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GRAVITY CONCENTRATION OF A NIOBIUM ORE SAMPLE SUBMITTED BY COMINCO, B.C.

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Mineral Processing Laboratory

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by

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J.P. Rouleau***, R.H. Bredin*** and D.R. McCarthy***

ABSTRACT

An ore sample assaying 0.5% Nb_2O_5 was examined for niobium extraction. Preliminary heavy liquid determinations indicated good liberation at relatively coarse size, suggesting possible favourable response to gravity concentration.

Niobium extraction was studied in the laboratory by various single and combined gravity separations methods: jig, table, spiral. The results of the selected flowsheet consisting of spiral and tabling concentration were verified in CPDU. A final product assaying 28.2% Nb_2O_5 at a niobium overall recovery of about 37% was obtained.

A recommended flowsheet for gravity concentration and a proposal for other routes of investigation were offered.

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INTRODUCTION

In 1983 at the request of COMINCO, B.C., an investigation was initiated by CANMET, under the START program, to evaluate the possibility of niobium extraction from an ore sample supplied by the company.

The investigation consisted mainly in determining the chemical composition of the sample, examining the ore mineralogy and carrying out testwork to upgrade the ore by gravity concentration methods. A target of minimum 15% Nb_2O_5 was set for the final product.

This report covers the results of the chemical analysis and gravity concentration tests. The findings of the mineralogical examination will be presented under separate cover.

OUTLINE OF THE INVESTIGATION

Testwork was carried out in laboratory and CPDU to investigate the possibility of niobium extraction from the COMINCO ore sample.

OBJECTIVES OF THE INVESTIGATION

The objectives of the investigation were:

a) Determine the chemical composition of the sample
b) Study the ore mineralogy, particularly with respect to niobium mineralization
c) Evaluate the possibility of niobium extraction by gravity concentration methods.

SUMMARY OF THE TESTWORK RESULTS

The results of the testwork are summarized as follows:

A. Sample head assay

The chemical assay of the sample indicated a content of 0.54% Nb_2O_5. No other element of interest was detected in the sample. More detailed analysis of the ore is presented in Table 2.

B. Sample mineralogy

The mineralogical study of the niobium sample will be presented under separate cover.

The only available information at this time is that one of the niobium carrier minerals is a calcium-niobium fersmite.

C. Niobium recovery by gravity concentration

Heavy liquid determinations indicated that a significant amount of niobium minerals presented good liberation in the -1.7 mm crushed ore.

Based on these results a test program was carried out to upgrade the niobium ore by gravity concentration.

Preliminary batch laboratory tests were first performed to evaluate the response of the ore to various methods of gravity concentration. Following the results of this testwork two flowsheet variants were selected: table concentration alone and a combined process of spiral and table.

Comparing the results of these two flowsheets it appeared that the best approach for treating this ore would be a combined spiral and table process. Therefore to confirm the results of the laboratory work a CPDU (continuous process development unit) run was performed applying the selected process.

The CPDU test consisted in the following stages:

- crushing the ore to -1.7 mm
- screening out the -0.074 mm fraction
- spiral concentration of the -1.7 + 0.074 mm ore
- grinding the spiral concentrate to -0.3 mm and removal of -0.074 mm fraction, by screening
- table concentration of the ground spiral concentrate

The flowsheet and the complete metallurgical results of the CPDU run are presented in Fig. 16 and Table 31 respectively. A summary of the results are given in Table 1.

Therefore, by combined spiral and table treatment of the ore, a final concentrate of 28.2% Nb_2O_5 was obtained at an overall weight yield and niobium recovery of 0.6% and 36.7% respectively.

Table 1 - Summary of the testwork results

Product	% Weight	Assay % Nb_2O_5	% Dist. Nb_2O_5
Head sample	100.0	0.46	100.0
Table final conc	0.6	28.2	36.7
Table midds - 2	0.2	7.95	3.5
Table midds - 1	1.0	0.85	1.9
Table tailing (reject)	14.7	0.16	5.2
Spiral conc -0.074 mm (reject)	4.1	1.93	17.1
Spiral tailing (reject)	55.8	0.17	20.5
Ore -0.074 mm (reject)	18.6	0.30	12.1
Dust from crushing (reject)	5.0	0.28	3.0

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the investigation to recover the niobium from this ore the following conclusions can be drawn:

1. The chemical assay of the ore sample indicated a niobium content (0.54 Nb_2O_5) somewhat lower than that of the Niobec ore (0.7% Nb_2O_5). Also, the mineralogical examination revealed the presence of fersmite as one of the main niobium carriers, a mineral almost unknown in the niobium processing industry. No other elements of possible economic interest were detected in the sample. The niobium content was however considered high enough to warrant an investigation to upgrade the ore.
2. The preliminary determinations: screen tests and assay per size fractions, heavy liquid experiments, etc., showed that even at a relatively coarse size the niobium minerals exhibited good liberation indicating the possibility of upgrading the ore by gravity concentration methods.
3. The findings of the preliminary determinations were confirmed by the laboratory and CPDU testwork which indicated that by a combined spiral and table process a relatively high-grade niobium concentrate could be obtained.

4. The niobium recovery in the final concentrate was however quite low: 36.7%. The main niobium losses were reported in the -74 μm fraction (ore and spiral concentrate) and in the spiral tailing. Almost 30% of the niobium was lost in the fine material -74 μm which was not processed by gravity methods. Gravity concentration is very inefficient when dealing with material below 74 μm and therefore not too much can be done to avoid the niobium losses in the fine material under this technological concept. A careful selection of crushing and screening equipment could reduce, by few percent, the amount of fines produced in this stage, lowering the niobium losses accordingly.

   The niobium lost in the spiral tailing represented 20.5% of the total metal contained in the sample. Heavy liquid determinations carried out on Spiral Tailing indicated that a substantial amount of relatively well liberated niobium minerals were discarded in this product. This loss could probably be drastically reduced. It is estimated, based on heavy liquid results, that approximately half of the niobium lost in the Spiral Tailing can be recovered in the concentrate either by a better adjustment of spiral operating conditions or by using other types of gravity concentration equipment.

5. Although the overall niobium recovery by gravity separation methods was low, the combined spiral and tabling process offers a relatively simple and pollution-free method of extracting part of the niobium from the ore, in a concentrate representing only 0.6%, by weight, of processed material. Also, by this method, 70%, by weight of the ore fed to the process could be removed as a tailing of low niobium content (0.17% Nb_2O_5).

The possibility exists that the niobium reporting in the fine fraction would be recovered by other methods of concentration thus improving the total metal extraction from the ore.

In conclusion, it is considered that this ore is a potential source of niobium production and the results of the testwork are sufficiently informative to warrant the continuation of the investigation for the niobium extraction.

The following recommendations for future testwork are offered.

a) Verify the results of this testwork on a larger scale (pilot plant) and in continuous operation.

The proposed flowsheet is presented in Fig. 1. The ore should be crushed to approximately -1.7 mm and the -0.074 mm fraction removed by screening. However an alternate route should be considered to process the unclassified ore. The crushed ore is then subjected to the first concentration stage consisting of a battery of spirals. Humphrey spiral, a newly developed Reichert portless spiral (Mark 7), and even the recently patented Spar MK.V high-grade cyclo-spiral concentrator should be tried.

The concentrate obtained in tne first gravity separation stage should be ground in a closed grinding-classification circuit to approximately -0.3 mm. A slightly coarser grind (-0.425 mm) could be tried to reduce the amount of ore reporting in the -0.074 mm fraction. The ground concentrate would be classified by a cyclone to remove the -0.074 mm fraction. The +0.074 mm fraction of the ground concentrate would then be upgraded by tabling, in two stages. In the first stage a rougher concentrate and tailing would be collected. The rougher concentrate would be reprocessed on the second tabling stage where the final concentrate would be separated. The middling product would be reground to -0.2 mm or finer and then returned to the cleaner table feed after desliming at 74 µm. The tailing produced in the first and second stage would represent the final table tailing. The optimum grinding size of the middlings would be based on the mineralogical examination and heavy liquid tests performed on the CPDU middlings as well as on the direct results of the table separation that would be carried out in the pilot plant.

b) Upgrading the table final concentrate by other methods than gravity concentration.

Further upgrading of the table concentrate should be tried based on the results of the chemico-mineralogical examination of the product. Impurities such as iron oxides could probably be removed by magnetic separation, heavy sulphides by flotation, and carbonates phosphates by leaching.

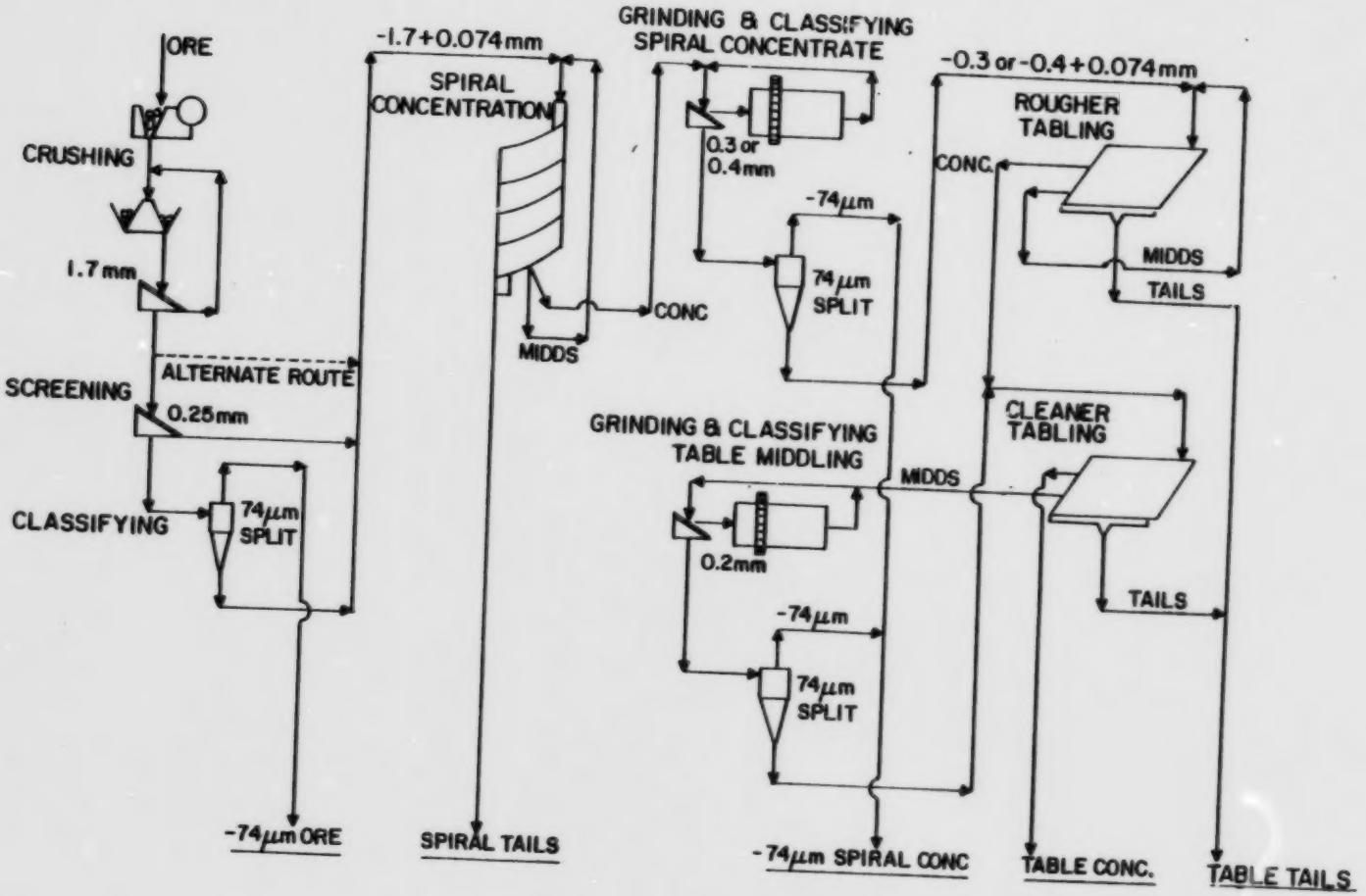

Fig. 1 - Proposed flowsheet for gravity concentration

c) Upgrading the ore by gravity concentration in successive stages without grinding of the concentrates obtained in various stages.
d) Recovery of niobium lost in the gravity concentration tailing by flotation.
e) Recovery of niobium from the entire ore by flotation.

Since a substantial amount of niobium cannot be recovered by gravity concentration due to the process inefficiency in the fine size range, it will be interesting to try to float the fine niobium lost in the tailing. Also the direct floation of the niobium from the ore should be investigated to be able to evaluate and compare the niobium extraction by two routes of treatment: combined gravity-flotation process versus direct flotation.

DETAILED DESCRIPTION OF THE TESTWORK

In this chapter are presented, in detail, the conditions and results of the investigation carried out to upgrade the niobium ore sample.

ORE SAMPLE

The niobium ore sample was received in September 1983 and consisted of -100 mm material contained in ten, 45-gallon drums. The net weight of the ore sample was about 2.5 tonnes. The ore sample was prepared for physico-chemical evaluation and testwork.

Sample preparation

The sample preparation consisted in the following steps:

- crushing the ore to -50 mm using a jaw crusher
- further crushing to -25 mm using a cone crusher.

This material was then stored in ten, 45-gallon drums.

The ore contained in three, 45-gallon drums was crushed to -1.7 mm, drum by drum, at various time intervals and used for laboratory testwork.

The rest of the ore was all crushed at the same time to -1.7 mm. Most of this crushed material was used for CPDU work. Only one drum of -1.7 mm ore was saved.

Crushing to -1.7 mm was carried out in a rod mill crusher working in closed circuit with a vibrating screen.

The weight distribution of the ore crushed to -1.7 mm is as follows:

Drum #1:	139.0 kg,	for laboratory work
Drum #2:	196.0 kg,	for laboratory work
Drum #3:	189.0 kg,	for laboratory work
Drum #4-9:	1555.6 kg,	for CPDU work
Drum #10:	320.0 kg,	saved
	126.7 kg,	dust produced by crushing
Total ore	2526.3 kg	

From the -1.7 mm crushed ore of drum #1 samples were riffled out for chemical assay, mineralogical examination, sieve analysis, heavy liquid determinations and laboratory testwork.

The ore from drum #2 and #3 was used for further laboratory testing and that from drum #4 to 9 was processed in the CPDU.

The scheme of the sample preparation work is given in Fig. 2.

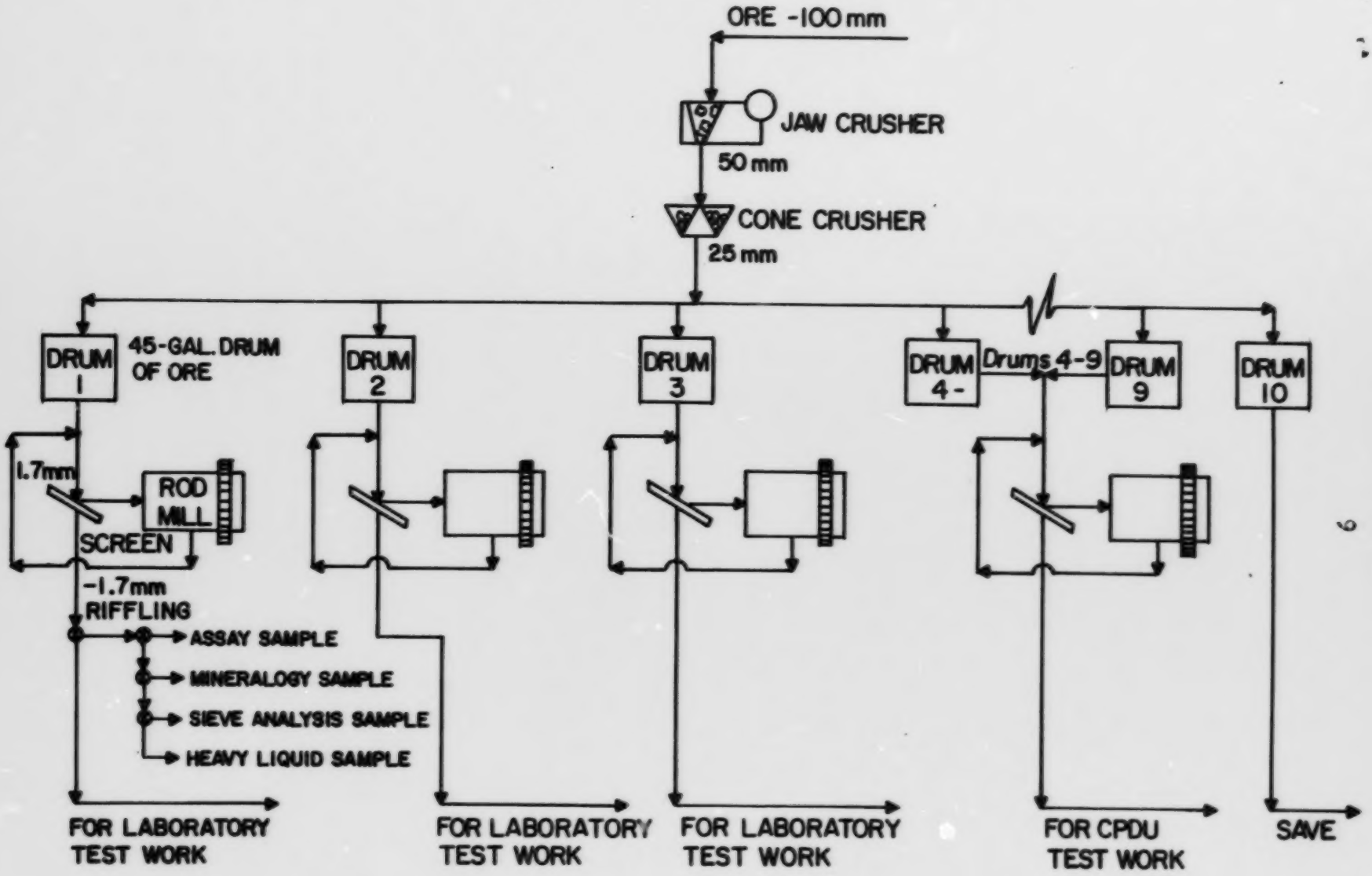

Fig. 2 - Scheme of sample preparation

Head assay

The chemical assay of the head sample is given in Table 2.

Table 2 - Head assay

Element	%	Element	%
Nb_2O_5	0.543	CaO	30.3
TaO_2	<0.008	SiO_2	2.55
P_2O_5	2.75	Al_2O_3	0.40
L.O.I.	43.8	MgO	15.2
Fe_2O_3	3.65	U	0.0005
TiO_2	0.04	Th	0.022

The element of interest in this sample is niobium. The tantalum content is very low. Also the concentration of radioactive elements is insignificant.

The ore sample contains a large amount of carbonates as indicated by the high proportion of CaO.

Mineralogical composition

The results of the mineralogical examination of the ore sample, as well as the findings of microscopic study of the polished sections obtained from products, will be presented under separate cover.

Sieve analysis

A portion of the ore sample crushed to -1.7 mm was subjected to screening and assay per size fractions to determine niobium distribution. The results are presented in Table 3.

The niobium distribution follows roughly the weight distribution per size fraction. There is some Nb_2O_5 concentration in the +600 micrometers fraction while the fine fractions, below 150 micrometers, exhibit a diminishing niobium assay content (except for -38 μm), indicating that a good part of the niobium minerals is present as coarse grained particles.

Table 3 - Sieve analysis of ore sample

Size		% weight			Nb_2O_5	
Mesh	Micro-meter	Retained Ind.	Retained Cum.	% pass. Cum.	(Ind. Retained) Assay %	% Dist.
+28	600	35.3	35.3	64.7	0.683	41.8
+35	425	10.6	45.9	54.1	0.609	11.3
+48	300	12.5	58.4	41.6	0.558	12.2
+60	250	6.0	64.4	35.6	0.541	5.7
+100	150	11.6	76.0	24.0	0.480	9.7
+150	106	5.7	81.7	18.3	0.435	4.3
+200	74	5.4	87.1	12.9	0.387	3.7
+400	38	4.7	91.8	8.2	0.376	3.1
-400		8.2	100.0	-	0.578	8.2
Head (calc)		100.0			0.576	100.0
Head (assay)					0.543	

Ind.: individual

O/A: overall

Heavy Liquid Determination

A series of heavy liquid determinations was performed to evaluate the amenability of the ore to concentration based on the difference in the specific gravity of the mineral constituents.

It was intended to determine the possibility of separating the niobium mineral, fersmite, (S.G. 4.5) from apatite (S.G. 3.2) and dolomite (S.G. 2.8-2.9).

The heavy liquid separation was carried out using methylene iodide (S.G. 3.33).

The fersmite and minor amounts of heavy minerals (iron oxides, sulphides) were expected to report in the sink fraction whereas the dolomite and the apatite should separate in the float product.

The ore crushed to -1.7 mm was classified down to 74 micrometers and each size fraction, except the -0.074 mm, was subjected to heavy liquid separation.

The results of these determinations are given in Table 4.

Table 4 - Results of heavy liquid tests

Size			% Weight		Assay %	% Dist. Nb_2O_5	
Mesh	Micrometer	Product	Ind.	O/A	Nb_2O_5	Ind.	O/A
		Sink	2.0	0.24	26.54	62.9	10.5
+14	+1180	Float	98.0	12.06	0.32	37.1	6.2
		Head fraction	100.0	12.3	0.844	100.0	16.7
		Sink	2.0	0.48	28.23	76.2	21.9
+28	+600	Float	98.0	23.72	0.18	23.8	6.9
		Head fraction	100.0	24.2	0.741	100.0	28.8
		Sink	1.9	0.42	27.61	77.0	18.4
+48	+300	Float	98.1	21.38	0.16	23.0	5.5
		Head fraction	100.0	21.8	0.682	100.0	23.9
		Sink	1.5	0.08	30.63	76.9	4.1
+60	+250	Float	98.5	5.42	0.14	23.1	1.2
		Head fraction	100.0	5.5	0.597	100.0	5.3
		Sink	1.6	0.21	22.31	73.6	7.6
+100	+150	Float	98.4	12.99	0.13	26.4	2.7
		Head fraction	100.0	13.2	0.485	100.0	10.3
		Sink	1.2	0.12	23.80	65.9	4.7
+200	+74	Float	98.8	10.18	0.15	34.1	2.5
		Head fraction	100.0	10.3	0.434	100.0	7.2
-200	-74	Head fraction	100.0	12.7	0.38	100.0	7.8
		Sink composite		1.55	26.97		67.2
		Float composite		85.75	0.18		25.0
		-74 µm		12.70	0.38		7.8
		Head		100.0	0.62		100.0

The following observations can be made from the data produced by the heavy liquid test:

- The niobium assay of the sink product increased with decreasing particles size, but only above 250 mm. In the finer size range the Nb_2O_5 content of the sink product dropped significantly. The explanation could be that some heavy minerals, other than fersmite,

unliberated at coarse size and reporting in the float product became liberated at finer sizes and sank, lowering the niobium content of the sink product.

- The niobium assay of the float product was somewhat high on the separation of +1180 mm fraction (0.32% Nb_2O_5), but became much lower (0.18-0.13% Nb_2O_5) in the finer size range. This indicated that below 1180 mm a relatively good liberation of the niobium minerals could be achieved.
- The recovery in Nb_2O_5 for each size fraction varied between 63-77% and the test overall extraction in niobium was 67.2%. Therefore a single or combined gravity concentration process is expected to perform around or below this value. Although the ore sample exhibited relatively good liberation in the coarse size range, at least one quarter of the niobium remained tied up in locked particles above 0.074 mm.

It was estimated that by gravity concentration the niobium extraction in products assaying 15-20% Nb_2O_5 would not exceed 50-60%.

GRAVITY CONCENTRATION

Following the results of the heavy liquid determinations it was considered appropriate to investigate the response of the ore sample to gravity concentration.

The testwork program consisted in the following series of experiments:

- Preliminary batch tests to investigate the niobium extraction from the ore sample by various gravity concentration methods and select the most efficient process variants
- Flowsheet development tests to perform a complete run of the selected process variants.
- CPDU (continuous process development unit) test to run a large quantity of ore under the best processing conditions and collect niobium concentrate for further treatment and evaluation.

Preliminary Batch Tests

The ore sample crushed to -1.7 mm was wet classified on 0.074 mm screen and the +0.0074 mm fraction was subjected to gravity concentration by various methods. The -0.074 mm fraction was obviously not suitable for gravity separation; however, to obtain an evaluation of the gravity concentration results for the entire size range, the -0.074 mm fraction was also included in the testwork program.

The following methods of gravity concentration were used in the testwork:

- Jigging
- Tabling
- Spiral concentration

Since the -1.7 + 0.074 mm fraction was considered too wide a size range for a single treatment by either jigging or tabling, this size fraction was further classified into narrower size ranges to better accomodate the application of these methods.

Spirals concentration was carried out using the -1.7 mm + 0.074 mm ore without further classification.

The -0.074 mm fraction was processed by tabling only.

A diagram showing the method of concentration used on various size ranges is given in Table 5.

The objective of the preliminary batch tests was to compare the performances of the gravity concentration methods in the first upgrading stage and to select the best variants for further flowsheets development. The selection of the process variants was based on niobium recovery at an arbitrarily set target of about 2% Nb_2O_5 assay of the rougher concentrate. Each process variant consisting in one or more methods of concentration covered the entire size interval above 0.074 mm. Only one orientative test was carried out with the -0.074 mm fraction but the processing of this material was not included in any technological variant at this stage.

Table 5 - Method of concentration per size fraction

Size fraction, mm/process					
-1.7 + 0.6	-0.6 + 0.4	-0.4 +0.3	-0.3 + 0.25	-0.25 + 0.0074	-0.074
Jig				Table	
Coarse Jig	Fine Jig			Table	
Ground to -0.4 mm		Table			
	Ground to -0.3 mm		Table		Table
		Ground to -0.25 mm		Table	
Spiral					

The following process variants were experimented:

1. Jig and Table
2. Coarse Jig, Fine Jig and Table
3. Table, ore ground to: -0.4; -0.3; -0.25 mm
4. Spiral.

Description of the testwork conditions and results follows.

1. Jig and Table

In this technological variant the ore crushed to -1.7 mm was classified on 0.25 mm and 0.074 mm screens. A 762 mm diam SWECO vibrating screen was used to classify at 0.25 mm and a double stage SWECO screens (762 mm and 610 mm diam) removed the -0.074 mm material.

The -1.7 + 0.25 mm fraction was subjected to jig tests while the -0.25 + 0.074 mm fraction was used for table experiments.

The -0.074 mm fraction was not processed. The scheme of jig and table testwork is shown in Fig. 3.

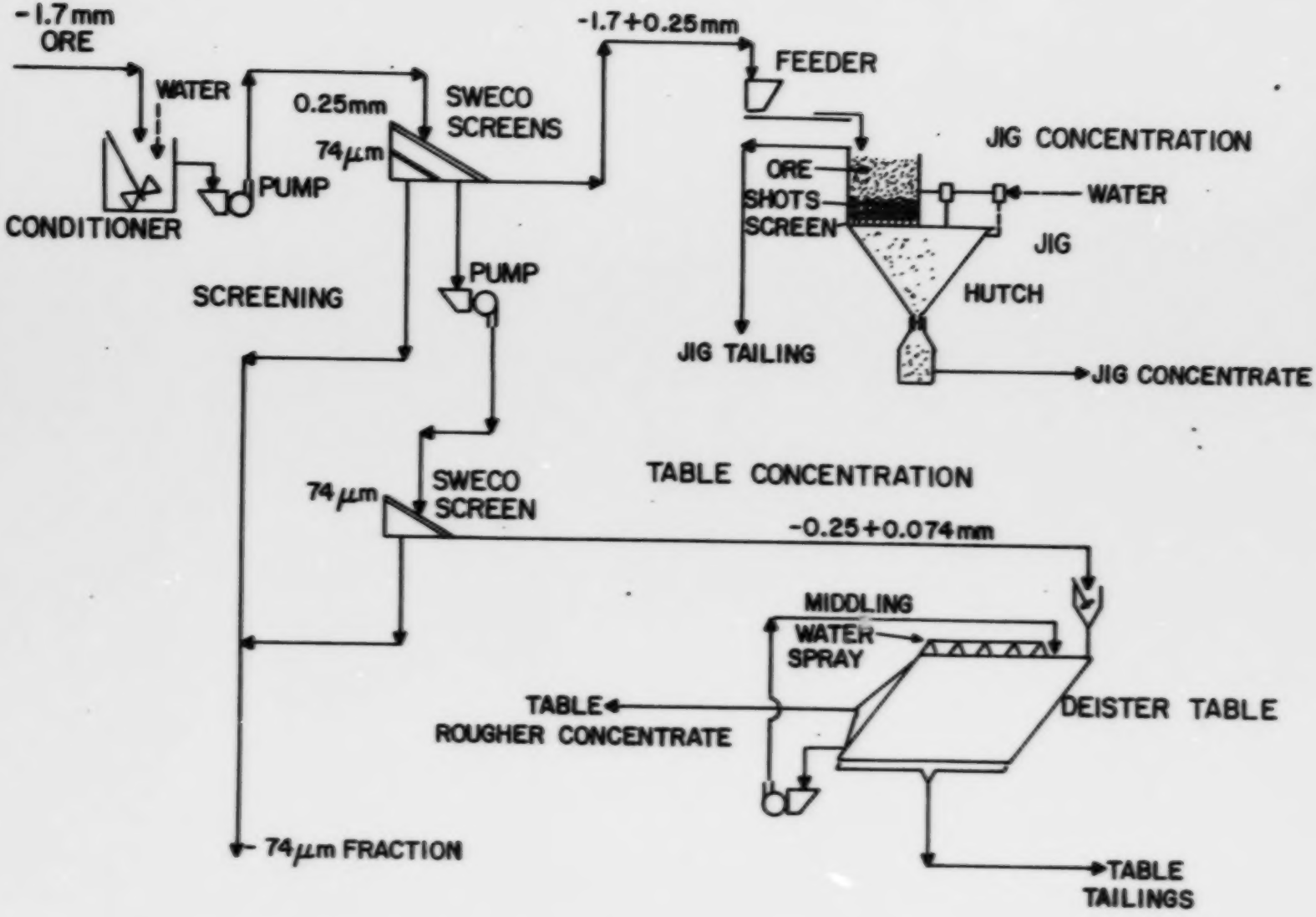

Fig. 3 - Scheme of jig and table laboratory testwork

a) Jig Tests

A Denver laboratory jig unit (100 x 150 mm) was used for the testwork.

The tests were carried out under the following conditions.

Feed rate	:	60 kg/h and 120 kg/h
Screen	:	2.36 mm (8 mesh) and 4.75 mm (4 mesh)
Bedding	:	Steel shots 3-5 mm for 2.36 mm screen and 6-7 mm for 4.75 mm screen. The weight of the shots was approximately 1800 g.
Stroke	:	3 mm (1/8 in.) and 6 mm (1/4 in.)
Speed	:	600 rpm
Water rate	:	Dilution: 6.3 to 20 L/min
		Wash : 5.0 to 20 L/min

All the tests were run in open circuit. Two products were collected: a concentrate that reported in the hutch and a tailing removed from the upper layer of the material pulsating in the jig compartment. No retreatment of the products was performed.

The conditions and results of the testwork are presented in detail, in Appendix A and summarized in Table 6.

Figures 4 and 5 give the variation of the weight yield and niobium recovery of the concentrate as a function of the concentrate grade. It appeared from the graphs that, the 120 kg/h feed rate gave better niobium recoveries than the 60 kg/h feed. Assuming a concentrate assay of approximately 1.8% Nb_2O_5, the recoveries in niobium, related to the jigging feed, at 120 kg/h and 60 kg/h were 39% and 30% respectively.

Table 6 - Summary of jig test results (-1.7 + 0.25 mm)

Test No.	Feed rate kg/h	Screen mm	Bedding mm	Stroke mm	Speed rpm	Water rate L/min		Concentrate			Tails
						Dilut.	Wash	% Weight	Assay % Nb_2O_5	% Dist. Nb_2O_5	Assay % Nb_2O_5
J-6	120	2.36	3-5	6.0	600	20.0	20.0	1.5	5.76	15.7	0.47
J-7		2.36	3-5	4.7		20.0	20.0	2.5	4.75	20.9	0.46
J-8		2.36	3-5	3.0		6.3	7.5	1.7	4.52	15.1	0.44
J-11		4.75	6-7	6.0		15.0	12.0	10.0	1.97	36.6	0.38
J-12		4.75	6-7	3.0		8.6	12.0	6.3	2.82	28.3	0.48
J-14	60	4.75	6-7	6.0	600	7.5	10.0	21.7	1.37	52.0	0.35
J-19		4.75	6-7	3.0		20.0	15.0	6.6	1.82	28.0	0.33
J-20		4.75	6-7	6.0		15.0	5.0	38.6	1.14	75.7	0.23
J-21		4.75	6-7	6.0		15.0	7.5	28.5	1.11	67.8	0.21
J-22		4.75	6-7	6.0		20.0	15.0	21.0	1.42	61.1	0.24

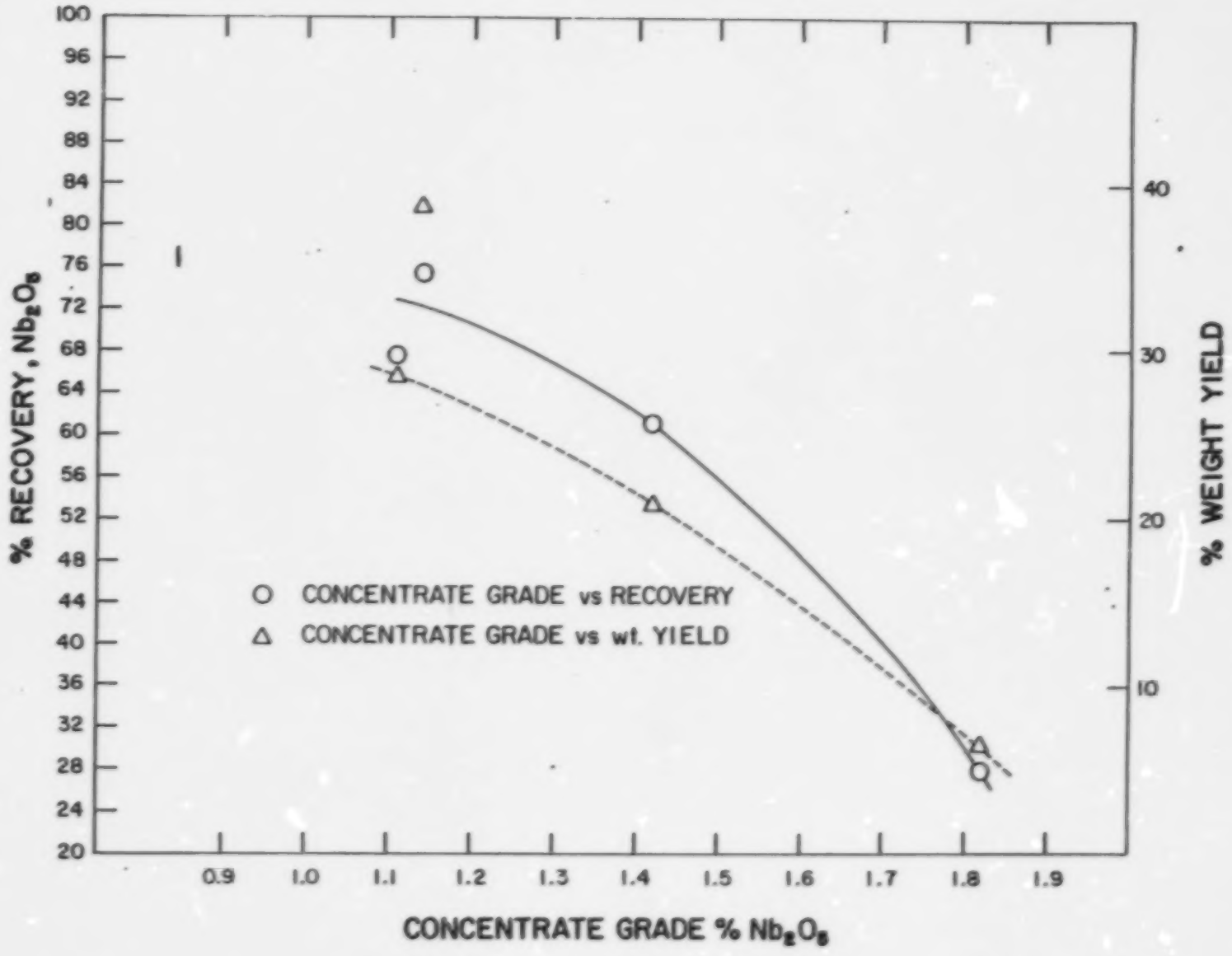

Fig. 4 - Jig concentration of -1.7 +0.25mm ore at 60 Kg/h feed rate

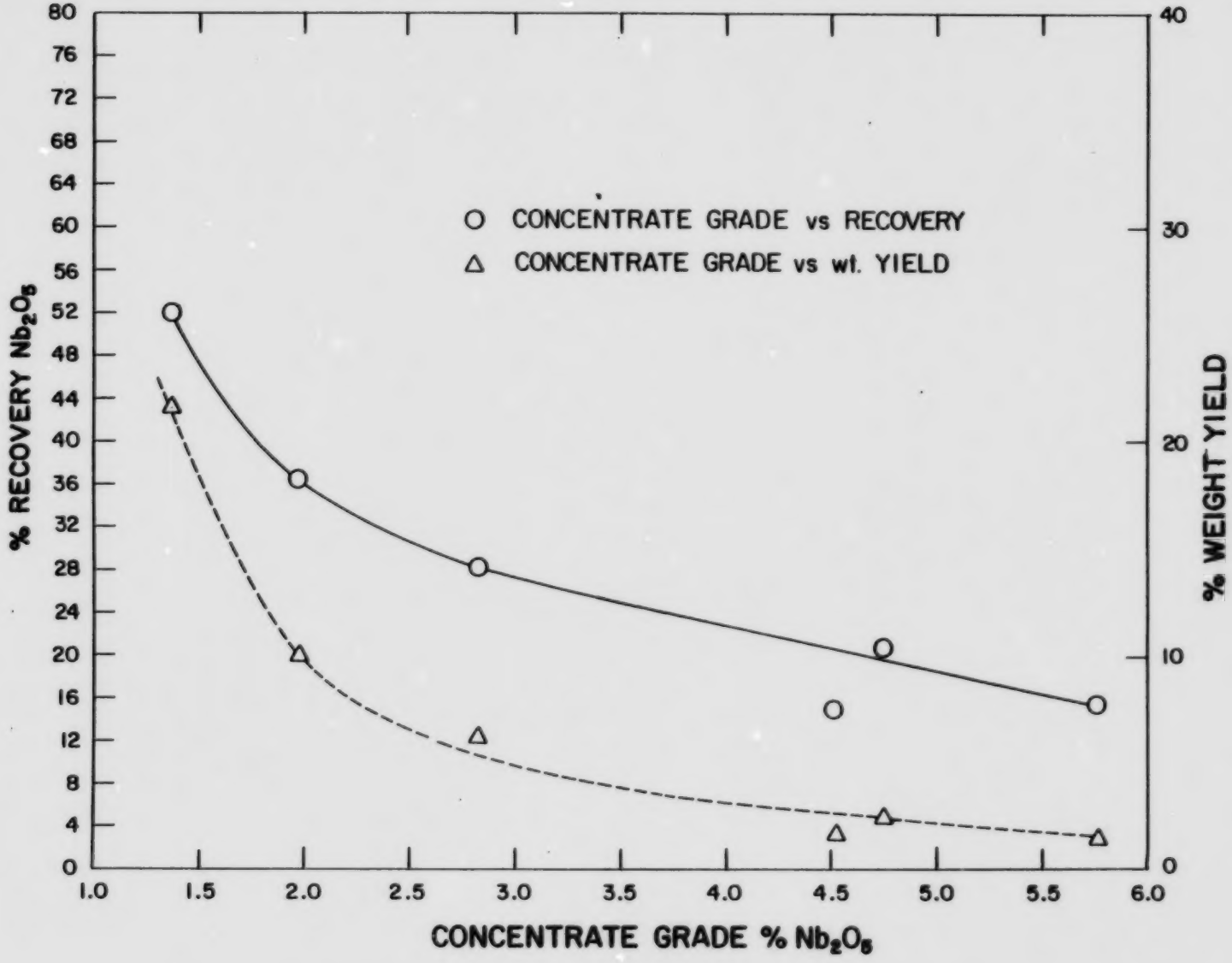

Fig. 5 - Jig concentration of -1.7 +0.25mm ore at 120 Kg/h feed rate

b) Table Tests

A Deister laboratory table was used for the test work.

Although the results of tabling the -0.25 + 0.076 fraction were to be evaluated at the rougher stage level, the testwork included a further upgrading of the rougher concentrate, in open circuit and with middlings recirculation. The results of this supplementary work are reported in the Appendix A but they were not used to evaluate the performance of the process variant at this stage.

The detailed conditions and results of tabling the -0.25 + 0.074 material are given in Appendix A and Fig. F-1, F-2, while Table 7 presents the metallurgical data obtained in the rougher stage.

Table 7 - Results of tabling the -0.25 + 0.074 mm fraction

Products	% Weight	Assay % Nb_2O_5	% Dist. Nb_2O_5
Head	100.0	0.458	100.0
Rougher Conc	13.9	2.267	68.8
Tailing	86.1	0.166	31.2

In the rougher stage a concentrate of approximately 2.3% Nb_2O_5 was obtained for a recovery in niobium, related to the table feed, of about 69%.

2. Coarse Jig, Fine Jig and Table

The ore sample crushed to -1.7 mm was wet classified on 0.25 and 0.074 mm screens like in the previous series of tests. However, to increase the efficiency of the jig treatment the -1.7 + 0.25 mm material was further classified into two fractions: -1.7 + 0.6 mm and -0.6 + 0.25 mm, after which they were separately subjected to jigging. This treatment was identified as coarse and fine jigging.

The results obtained in the previous tests by tabling the -0.25 + 0.074 mm fraction were used to compare the metallurgical data for this process variant.

One table test was run with the -0.6 + 0.25 mm fraction, trying to replace the fine jigging by tabling, but the separation was very poor and the test was discarded.

The -0.074 mm fraction was not processed.

The scheme of coarse jig, fine jig and table testwork is shown in Fig. 6.

a) Coarse Jig

The coarse fraction -1.7 + 0.6 mm was processed by jigging using the same laboratory jig unit as the previous test.

The tests were carried out under the following conditions:

Feed rate	:	60 kg/h
Screen	:	4.75 mm (4 mesh)
Bedding	:	1800 g steel shots 6-7 mm
Stroke	:	3 mm (1/8 in.) and 6 mm (1/4 in.)
Speed	:	600 rpm
Water rate	:	Dilution: 8.6-20 L/min
		Wash : 5.0-15 L/min

The conditions and results of the testwork are presented in detail, in Appendix B and summarized in Table 8.

Figure 7 shows the relationship between the weight yield or niobium recovery of the concentrate and the concentrate grade.

At about 2% Nb_2O_5 content of the concentrate the extraction in niobium related to the coarse fraction head was 59%.

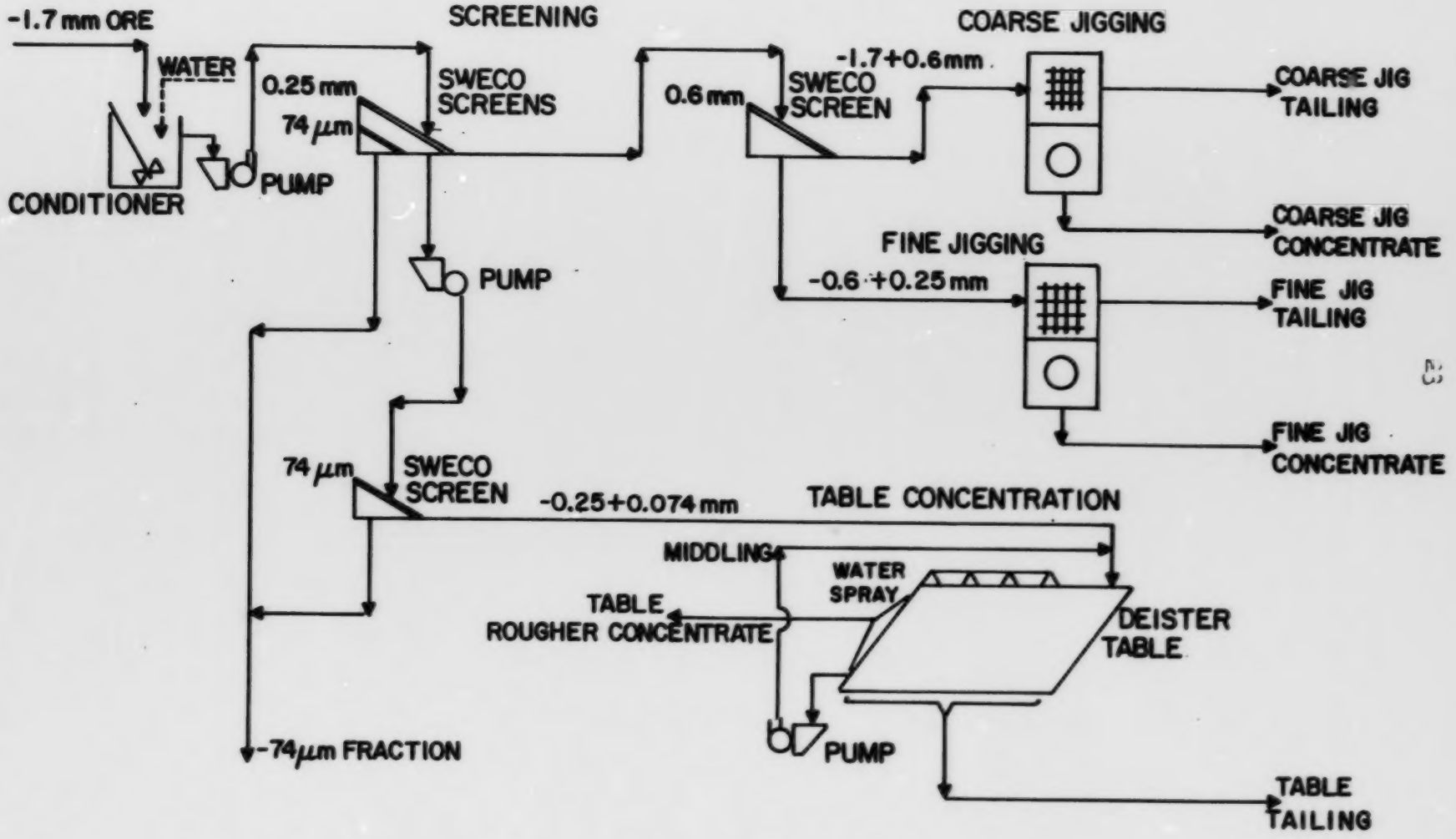

Fig. 6 - Scheme of coarse jig, fine jig and table laboratory testwork

Table 8 - Summary of coarse jig results

Test No.	Feed rate kg/h	Screen mm	Bedding mm	Stroke mm	Speed rpm	Water rate L/min		Concentrate			Tails
						Dilut.	Wash	% Weight	Assay % Nb_2O_5	% Dist. Nb_2O_5	Assay % Nb_2O_5
J-15	60	4.75	6-7	6	600	15.0	7.5	22.4	1.32	66.7	0.19
J-23				6		20.0	15.0	14.6	2.33	58.7	0.28
J-24				3		15.0	7.5	4.0	4.63	41.7	0.27
J-25				3		8.6	5.0	14.7	2.46	52.1	0.39

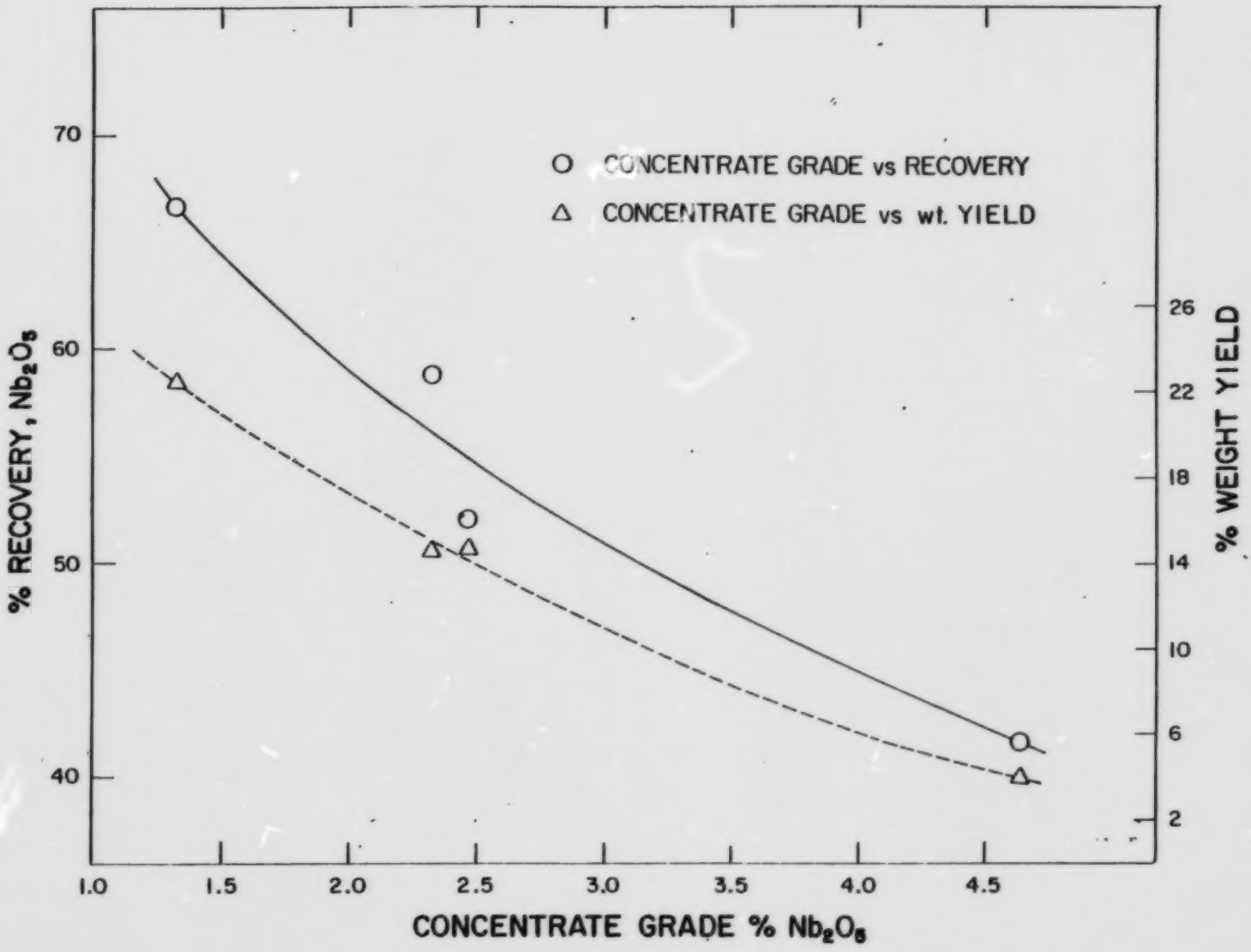

Fig. 7 Jig concentration of -1.7 + 0.6 mm ore at 60 kg/h feed rate

b) Fine Jig

Using the same jig laboratory unit the testwork with -0.6 + 0.25 mm fraction was carried out under the following conditions:

Feed rate	:	60 kg/h
Screen	:	2.36 mm (8 mesh)
Bedding	:	1700 g steel shots, 3-5 mm
Stroke	:	3 mm
Speed	:	600 rpm
Water rate	:	Dilution: 15-20 L/min
		Wash : 7.5-15 L/min

The conditions and results of the tests are presented in detail, in Appendix B and summarized in Table 9.

Figure 8 shows the variation of weight yield and niobium recovery in the concentrate as a function of concentrate grade.

At about 2% Nb_2O_5 content of the concentrate the extraction in niobium, related to the fine fraction head assay, was 40.5%.

Table 9 - Summary of fine jig results

Test No.	Feed rate kg/h	Screen mm	Bedding mm	Stroke mm	Speed rpm	Water rate L/min		Concentrate			Tails
						Dilut.	Wash	% Weight	Assay % Nb_2O_5	% Dist. Nb_2O_5	Assay % Nb_2O_5
J-27						20	7.5	10.6	1.88	41.8	0.31
J-29	60	2.36	3-5	3	600	15	7.5	18.1	1.41	48.6	0.33
J-30						20	15.0	4.3	3.89	32.1	0.37

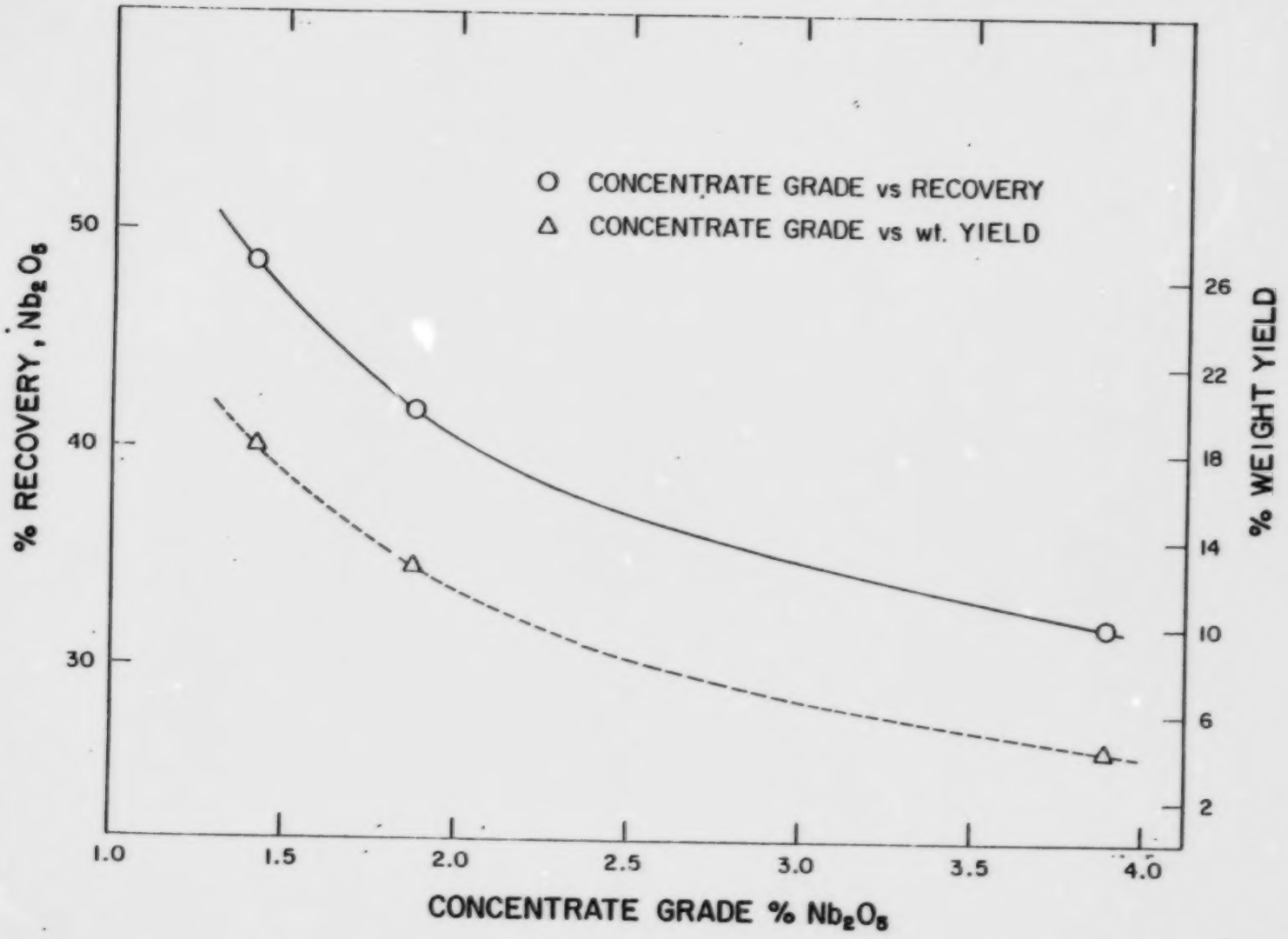

Fig. 8 Jig concentration of -0.6 + 0.25 mm ore at 60 kg/h feed rate

c) Table Tests

The conditions and results of tabling the -0.25 + 0.074 mm fraction have been already presented in the previous chapter dealing with jig-table variant.

3. Table

Table testwork was performed to investigate the possibility of upgrading the niobium ore by tabling only.

The ore crushed to -1.7 mm was further ground to various sizes and the -0.074 mm fraction was screened out. The +0.074 mm ore was subjected to tabling using the sand deck of a laboratory Deister table. Only one informative test was carried out with the -0.074 mm fraction using the slime deck of the same table.

The main purpose of these tests was to evaluate the results of upgrading the niobium ore by table, as a single process, in comparison with other single or combined gravity concentration methods. The results were evaluated and compared at the rougher stage concentration. However, to determine the possibility of further upgrading the table rougher concentrate, the products obtained in the first stage were re-treated on the same table using various circuit scheme.

The table tests were carried out under the following basic conditions:

Grind : -0.4; -0.3; -0.25 mm (-0.074 mm fraction removed)
Deck : Sand or slime
Slope : 7°
Stroke : 12 mm
S.P.M. : 155

Feed and water rates were not monitored. The scheme of table testwork is shown in Fig. 9.

The ore was ground in a laboratory grinding mill of 250 mm diam using a grinding load of 11.4 kg steel ball. The ore was first screened at the intended grinding size and the oversize ground in charges of 2 kg at a slurry density of 60% solids. The grinding was carried out in two stages with

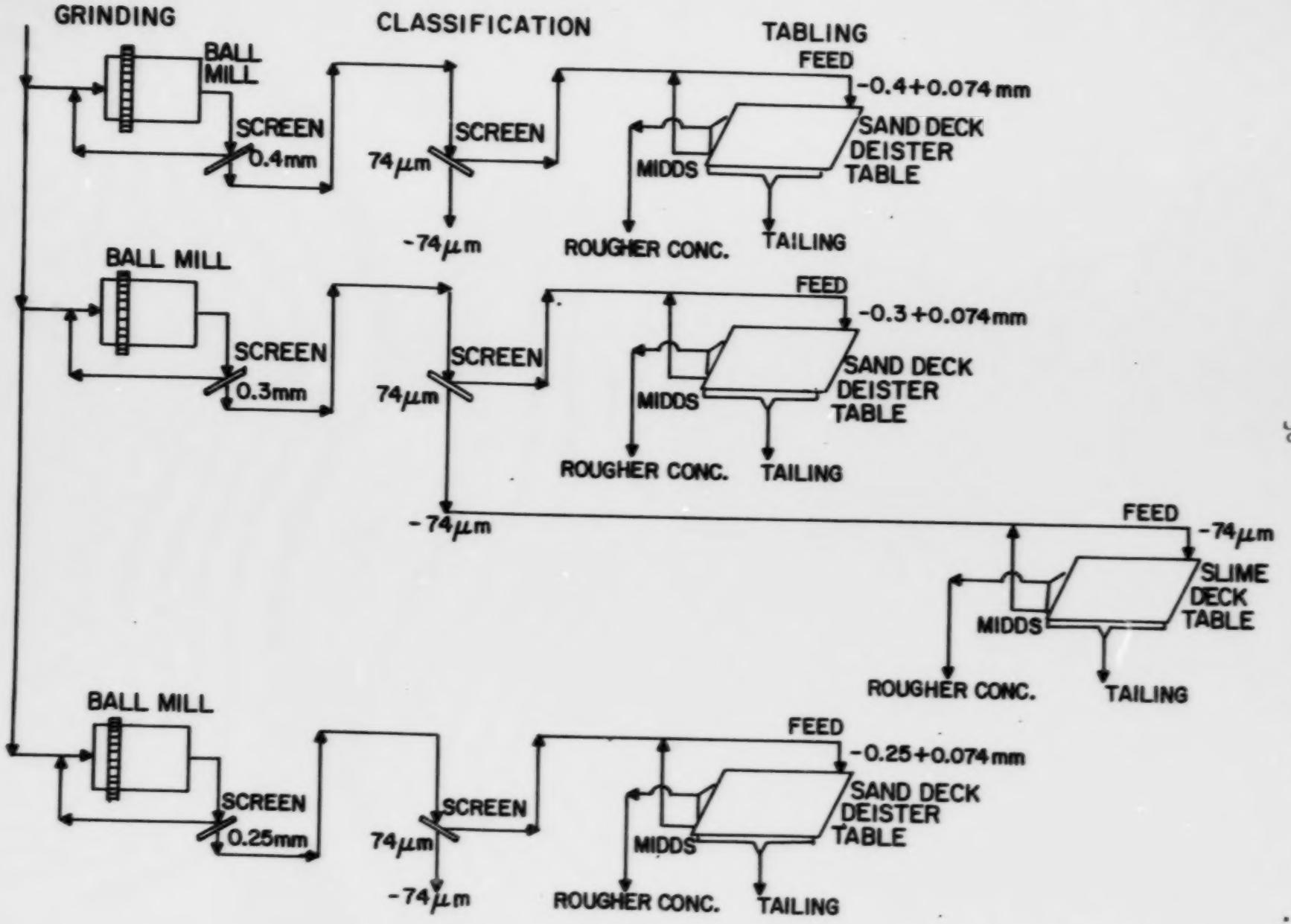

Fig. 9 Scheme of table laboratory tests

screening between stages to avoid overgrinding. The following grinding times were used:

10 + 10 min for -0.25 mm grind
8 + 10 min for -0.30 mm grind
6 + 8 min for -0.425 mm grind

The oversize of the last grinding stage was reground for 5-10 min in a small mill (200 mm diam) with 6.8 kg steel balls.

The size and niobium distribution in the +0.074 mm and -0.074 mm fractions resulting from each grind are given in Table 10.

Table 10 - Size and niobium distribution at various grinds

Grind mm	Size fraction	% Weight	Assay % Nb_2O_5	% Dist. Nb_2O_5
	Head	100.0	0.53	100.0
-0.25	+0.074 mm	59.9	0.516	58.8
	-0.074 mm	40.1	0.54	41.2
	Head	100.0	0.50	100.0
-0.30	+0.074 mm	65.6	0.48	62.9
	-0.074 mm	34.4	0.54	37.1
	Head	100.0	0.46	100.0
-0.425	+0.074 mm	76.2	0.44	72.3
	-0.074 mm	23.8	0.54	27.7

Detailed conditions and results of the table tests are given in Appendix C.

Figure 10 shows the relationship between the niobium recovery and the concentrate grade for -0.25; -0.3 and -0.4 mm grinding.

A summary of the most significative table tests results at rougher stage concentration of +0.074 mm fraction are given in Table 11.

The optimum results of tabling the +0.074 mm fraction were obtained under -0.30 mm grind, where an overall niobium recovery of approximately 52% was produced. At a finer grind a better minerals liberation was obtained and

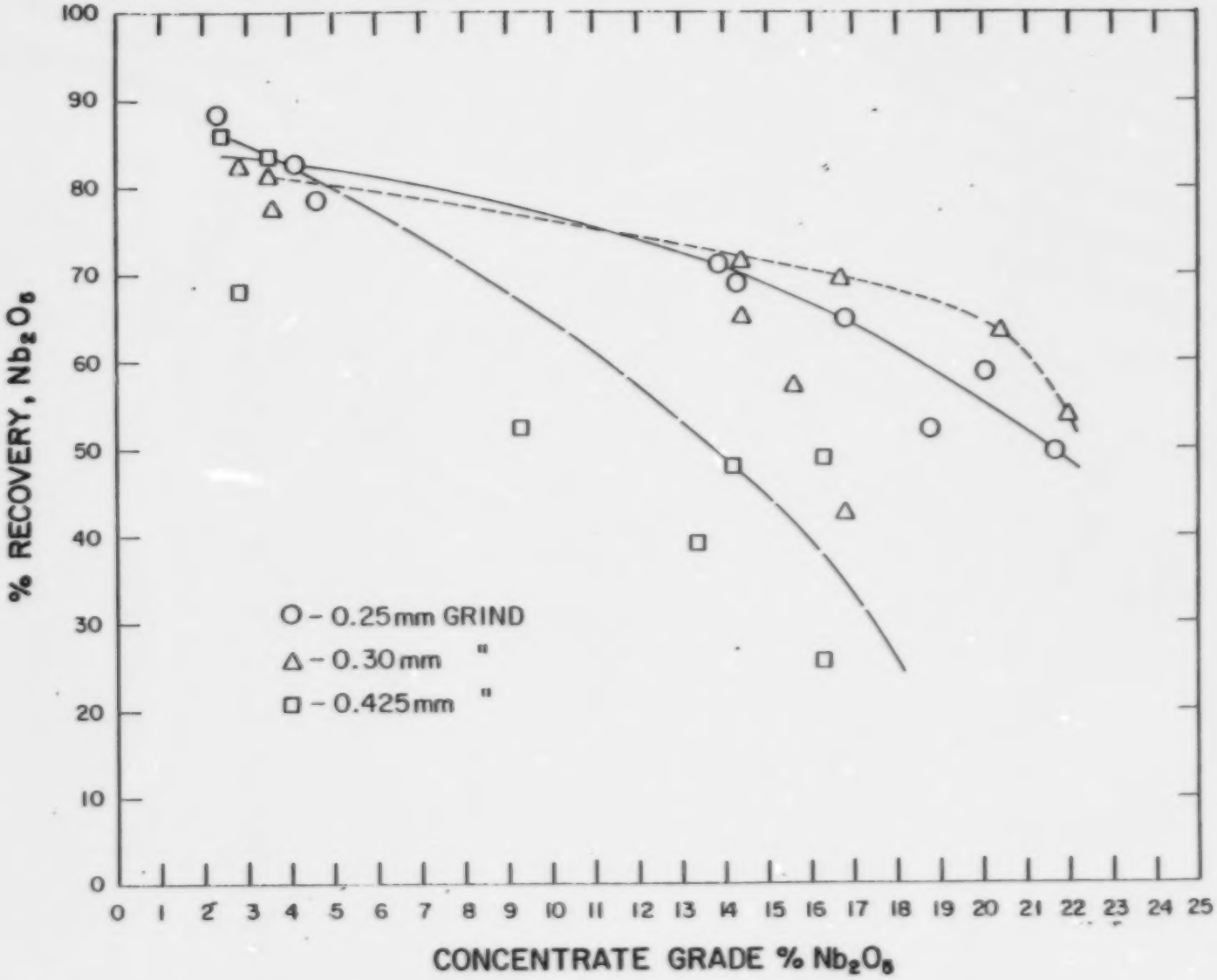

Fig. 10 Table concentration

Table 11 - Summary of table test results (+0.074 mm)

Grind mm	Test No.	Products	% Weight Ind	% Weight O/A	Assay % Nb_2O_5	% Dist. Nb_2O_5 Ind	% Dist. Nb_2O_5 O/A
		Head	100.0	59.9	0.468	100.0	58.8
-0.25	T-5	Concentrate	15.0	9.0	2.75	88.4	52.0
		Tailing	85.0	50.9	0.064	11.6	6.8
		Head	100.0	65.6	0.489	100.0	62.9
-0.30	T-6	Concentrate	14.2	9.3	2.84	82.4	51.8
		Tailing	85.8	56.3	0.10	17.6	11.1
		Head	100.0	76.2	0.444	100.0	72.3
-0.425	T-16	Concentrate	10.8	8.2	2.79	67.9	49.1
		Tailing	89.2	68.0	0.16	32.1	23.2

the table recovered more niobium in the concentrate, related to the table feed. However, since at -0.25 mm grind, less niobium reported in the +0.074 mm fraction than for the -0.30 mm grind, the overall table recoveries of the two grinding conditions were practically the same. Therefore for the same niobium recovery preference was given to tabling the -0.3 mm ground ore.

By tabling the -0.425 mm ground ore, the niobium loss in the tailing was much higher than that resulting from the other two grinds.

Since -0.3 mm grind was found to be best suited for tabling the +0.074 mm materials one orientative table test was carried out with the -0.074 mm fraction obtained from -0.3 mm grind.

A slime deck table was used for this test. The conditions and results of the test are presented in Appendix C. The rougher stage results are given in Table 12.

Table 12 - Results of tabling the -0.074 mm fraction

Test No.	Product	% Weight Ind	% Weight O/A	Assay % Nb_2O_5	% Dist. Nb_2O_5 Ind	% Dist. Nb_2O_5 O/A
	Head	100.0	34.4	0.449	100.0	37.1
T-18	Conc	10.8	3.7	1.35	32.5	12.1
	Tails	89.2	30.7	0.34	67.5	25.0

As expected poor concentration results were obtained by tabling the fine material.

4. Spiral

Upgrading of the niobium ore was also investigated by spiral concentration.

The ore crushed to -1.7 mm was classified on 0.074 mm screen and the -1.7 + 0.074 mm material was used to perform the spiral tests. Several tests were run with -1.7 mm unclassified ore but the results of these tests were not conclusive.

The equipment used to run the spirals tests was a closed circuit unit (Fig. 11) consisting of a standard size 5 turn Humphrey Spiral with accessory pump, tank, hydrocyclone, piping and hose.

The unit operated as follows: for each test a batch of slurry was prepared in the tank and was kept under mechanical agitation. The pump was started and the slurry entered the cyclone. The cyclone underflow represented the spiral feed, while the overflow was the wash water supply. The variable speed pump allowed to vary the feed rate to the spiral. Three products were obtained: concentrate, middling and tailing. The wash water was distributed among the products, most of it reporting in the tailing box. All three products and the excess wash water discharged in the tank and were again pumped to the cyclone to restart the same cycle.

The spiral performance was controlled by adjusting the splitters setting and the wash water addition.

Density and flowrate measurement together with products simultaneous sampling was used to monitor and evaluate the results of spirals concentration.

The spiral tests were carried out under the following basic conditions:

Feed rate	:	1.4 - 2.4 t/h
Density of the feed pulp	:	25-40% solids
Feed flowrate	:	50-90 L/min
Wash water rate	:	25-40 L/min

Detailed conditions and results of the spiral tests are presented in Appendix D.

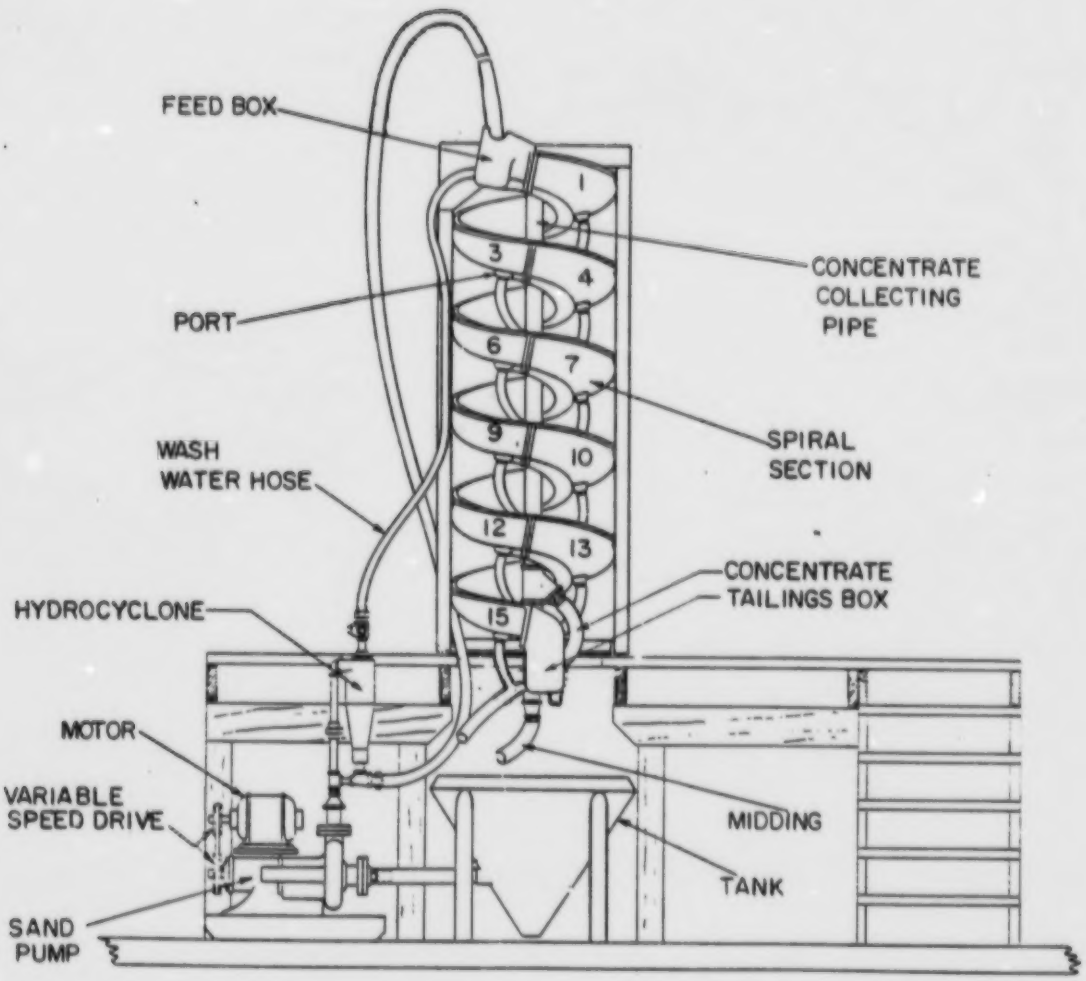

Fig. 11 Equipment set-up for spiral laboratory testwork

A summary of the spiral tests results is given in Table 13, while in Fig. 12 the niobium recovery and the weight yield were plotted as a function of the concentrate grade.

Table 13 - Summary of spiral tests results

Test No.	Feed rate t/h	Feed density % solids	Concentrate			
			% Weight	% Nb_2O_5	% Dist. Nb_2O_5 Ind	% Dist. Nb_2O_5 O/A
SP-2	1.753	37.6	35.8	0.94	78.6	72.5
SP-3	2.159	33.6	26.1	1.36	72.4	66.8
SP-10	1.790	30.0	21.4	2.33	68.6	63.2
SP-11	1.900	30.0	13.8	2.75	60.9	56.2
SP-12	1.690	30.0	36.0	1.41	81.5	75.1
SP-13	1.370	30.0	32.2	1.72	78.4	72.3
SP-14	1.800	30.0	24.1	1.81	71.2	65.6
SP-16	2.400	38.9	17.3	1.57	58.8	54.2
SP-20*	1.900	27.7	23.2	1.43	70.8	70.8

*Unclassified ore.

It appeared from these data that the spiral processing of classified ore, without middling recirculation, would result in a niobium recovery in excess of 70%, related to spiral feed, or 65% niobium extracted from the head sample, at a concentrate grade of about 1.8% Nb_2O_5. Middling recirculation to the feed is expected to increase the niobium recovery in the concentrate by approximately 5 points.

The processing of the unclassified ore gave, in one test, an overall niobium recovery of 70.8%, but insufficient data were obtained to substantiate these results. More tests are required to evaluate the spiral concentration of unclassified ore which presents the advantage of eliminating the screening step without losing too much values in the spiral tailing.

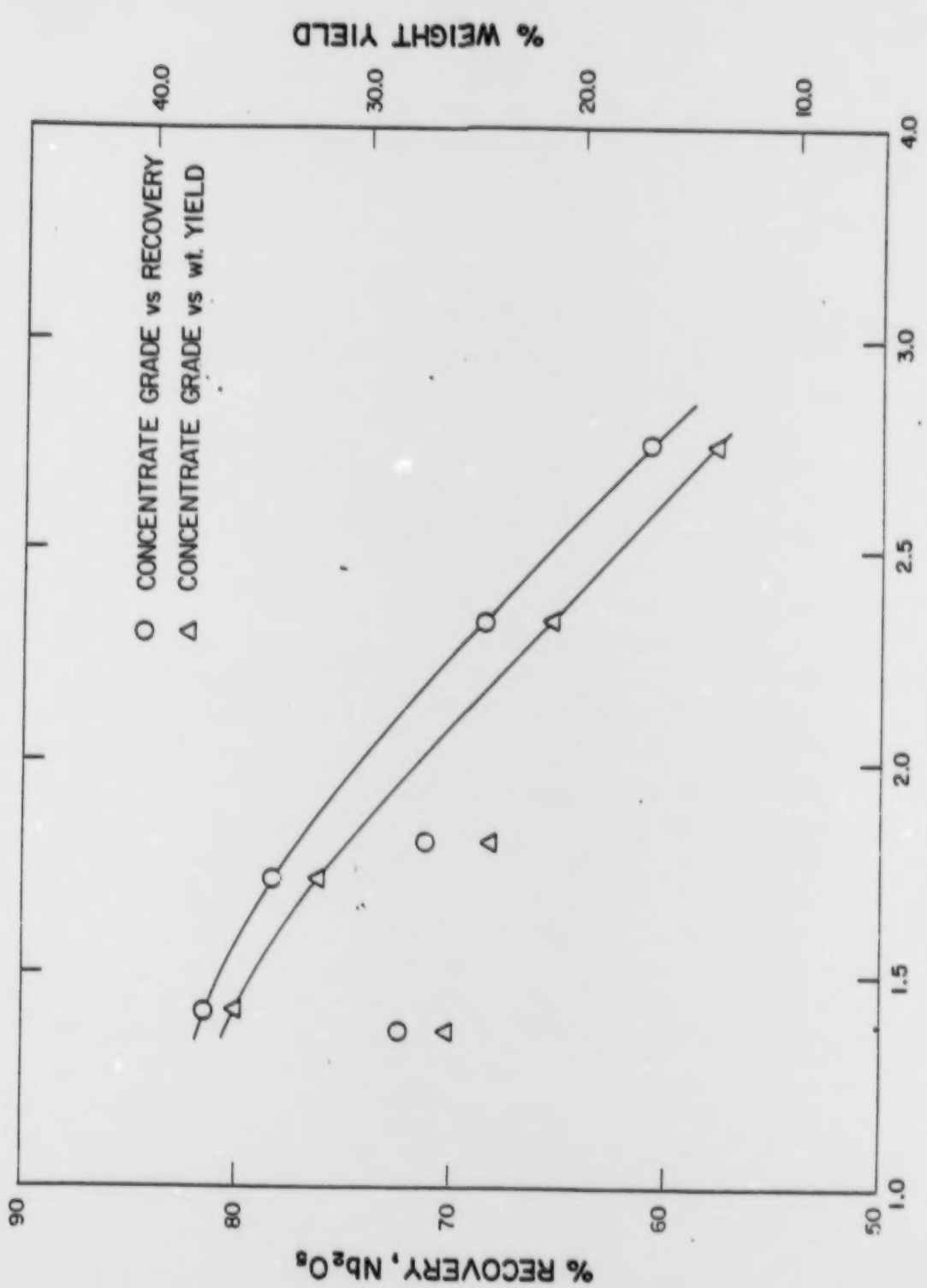

Fig. 12 Spiral concentration

5. Comparison of the Process Variants Results

Four process variants were selected based on the jig, table and spiral tests:

Variant 1: Jig -1.7 + 0.25 mm and Table -0.25 + 0.074 mm
Variant 2: Coarse Jig -1.7 + 0.6 mm, Fine Jig -0.6 + 0.25 mm and Table -0.25 + 0.074 mm
Variant 3: Table -0.3 + 0.074 mm
Variant 4: Spiral -1.7 + 0.074 mm

The technological schemes of the process variants were shown in Fig. 13.

The metallurgical results of the variants are presented for comparison in Table 14.

The performance of the process variant identified as "Jig and Table" was evaluated based on the results of Test J-11 for jigging the -1.7 + 0.25 mm fraction and Test T-1 for tabling the -0.25 + 0.074 mm material. By combined jig and table process a concentrate of 9.7% by weight was obtained, assaying approximately 2% Nb_2O_5 for a recovery in niobium related to the head sample of about 40%.

The performance of the process variant identified as "Coarse Jig, Fine Jig and Table" was evaluated based on the graph presented in Fig. 7 for jigging the coarse fraction -1.7 + 0.6 mm and on the results of Test J-27 for jigging the fine fraction -0.6 + 0.25 mm. The results of tabling the -0.25 + 0.074 mm material were taken from Test T-1 as for the process variant 1. The combined process of coarse and fine jigging with table treatment yielded a rougher concentrate of 12.4% by weight, assaying 2.04% Nb_2O_5 and representing an extraction in niobium related to the head sample of 50.6%.

The process variant identified as "Table" consisted in tabling the -0.3 + 0.074 mm ore and was based on Test T-6 results. The rougher concentrate represented a weight yield of 9.3% and assayed 2.84% Nb_2O_5 for a recovery in niobium related to the head sample of 51.8%.

The process variant identified as "Spiral" consisted in processing the -1.7 + 0.074 mm ore by spiral in a closed circuit unit. The performances of this variant were evaluated based on Test SP-14. The concentrate obtained represented a weight yield of 21.3% and assayed 1.81% Nb_2O_5 for an extraction in niobium related to the head sample of 65.6%.

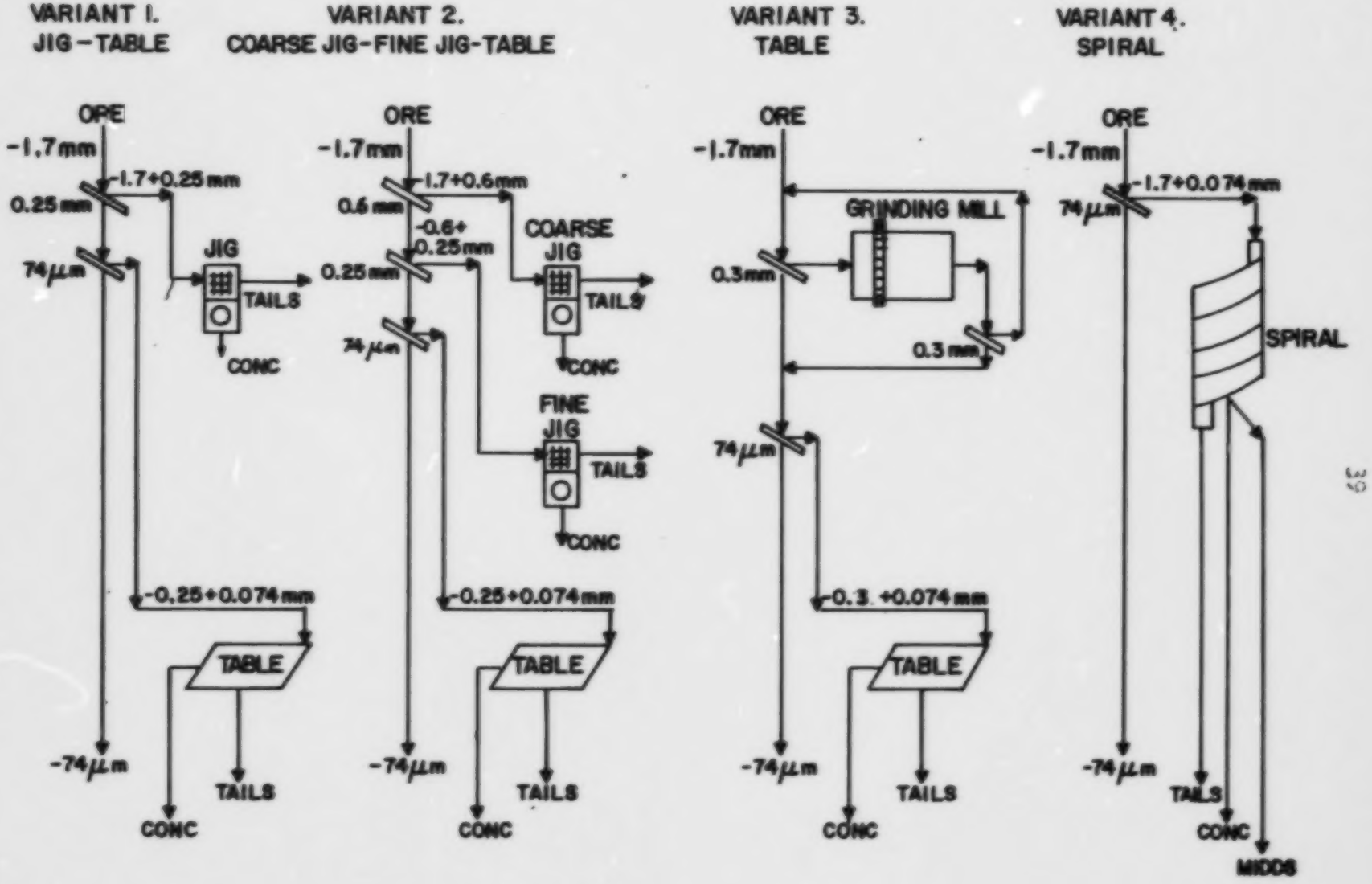

Fig. 1. Technological schemes of selected process variants

Table 14 - Comparison of process variants results

Process variant	Operating stages	Product	% Weight		Assay % Nb_2O_5	% Dist. Nb_2O_5	
			Ind	O/A		Ind	O/A
	Crushing: -1.7 mm	Head	100.0	100.0	0.50	100.0	100.0
	Classification:	-1.7 + 0.25 mm	66.2	66.2	0.54	71.0	71.0
	0.25 mm	-0.25 + 0.074 mm	22.3	22.3	0.458	20.3	20.3
	0.074 mm	-0.074 mm	11.5	11.5	0.38	8.7	8.7
	Jig:	Feed	100.0	66.2	0.54	100.0	71.0
Jig	-1.7 + 0.25 mm	Conc	10.0	6.6	1.97	36.6	26.0
+		Tails	90.0	59.6	0.38	63.4	45.0
	Table:	Feed	100.0	22.3	0.458	100.0	20.3
Table	-0.25 + 0.074 mm	Conc	13.9	3.1	2.267	68.8	14.0
		Tails	86.1	19.2	0.166	31.2	6.3
	Combined	Head		100.0	0.50		100.0
	Jig + Table	Conc		9.7	2.065		39.9
		Tails		78.8	0.328		51.4
		-0.074 mm		11.5	0.38		8.7

Table 14 (Cont'd)

Process variant	Operating stages	Product	% Weight		Assay % Nb_2O_5	% Dist. Nb_2O_5	
			Ind	O/A		Ind	O/A
	Crushing: -1.7 mm	Head	100.0	100.0	0.50	100.0	100.0
	Classification:	-1.7 + 6.0 mm	35.3	35.3	0.583	41.3	41.3
	0.60 mm	-0.6 + 0.25 mm	29.1	29.1	0.48	28.0	28.0
	0.25 mm	-0.25 + 0.074 mm	22.7	22.7	0.458	20.9	20.9
	0.074 mm	-0.074 mm	12.9	12.9	0.38	9.8	9.8
Coarse Jig	Coarse Jig	Feed	100.0	35.3	0.583	100.0	41.3
	-1.7 + 0.60 mm	Conc	17.2	6.1	2.00	59.0	24.4
+		Tails	82.8	29.2	0.289	41.0	16.9
Fine Jig	Fine Jig	Feed	100.0	29.1	0.48	100.0	28.0
	-0.6 + 0.25 mm	Conc	10.6	3.1	1.88	41.8	11.7
+		Tails	89.4	26.0	0.31	58.2	16.3
Table	Table:	Feed	100.0	22.7	0.458	100.0	20.9
	-0.25 + 0.074 mm	Conc	13.9	3.2	2.267	68.8	14.4
		Tails	86.1	19.5	0.166	31.2	6.5
	Combined	Head		100.0	0.50		100.0
	Coarse Jig +	Conc		12.4	2.04		50.6
	Fine Jig +	Tails		74.7	0.264		39.6
	Table	-0.074 mm		12.9	0.38		9.8

Table 14 (Cont'd)

Process variant	Operating stages	Product	% Weight		Assay % Nb_2O_5	% Dist. Nb_2O_5	
			Ind	O/A		Ind	O/A
Table	Crushing: -1.7 mm	Head	100.0	100.0	0.50	100.0	100.0
	Grinding: -0.3 mm	-0.3 + 0.074 mm	65.6	65.6	0.48	62.9	62.9
	Classification: 0.074 mm	-0.074 mm	34.4	34.4	0.54	37.1	37.1
	Table: -0.3 + 0.074 mm	Feed	100.0	65.6	0.49	100.0	62.9
		Conc	14.2	9.3	2.84	82.4	51.8
		Tails	85.8	56.3	0.10	17.6	11.1
Spiral	Crushing: -1.7 mm	Head	100.0	100.0	0.56	100.0	100.0
	Classification: 0.074 mm	-1.7 + 0.074 mm	88.5	88.5	0.587	92.2	92.2
		-0.074 mm	11.5	11.5	0.38	7.8	7.8
	Spiral: -1.7 + 0.074 mm	Feed	100.0	88.5	0.61	100.0	92.2
		Conc	24.1	21.3	1.81	71.2	65.6
		Midds	13.9	12.3	0.51	11.6	10.7
		Tails	62.0	54.9	0.17	17.2	15.9

By examining and comparing the performances of these four process variants it appeared that the most promising results for further flowsheet development tests were offered by the variants "Table" and "Spiral". Therefore the testwork to upgrade the niobium ore was continued based on these two methods of concentration.

Flowsheet Development Tests

The results of the preliminary batch tests indicated that among the gravity concentration methods tried on this niobium ore, table and spiral, as a single process, yielded the best metal recoveries in the rougher stage.

The next step in the test program was to develop one or more flowsheet variants, by which the ore sample could be upgraded to a target grade of minimum 15% Nb_2O_5.

It was already known from the results of table batch tests, that table alone using a number of cleaner and recleaner stages would achieve the 15% Nb_2O_5 concentration target. Therefore the development of a flowsheet based entirely on table processing was the first obvious choice.

However, table for this application will require further grinding after which more fine material will be produced that could not efficiently be treated by a gravity process.

Since spiral processing also resulted in relatively good niobium recovery in the rougher stage and had the advantage against tabling for not requiring an extra grinding, it was considered appropriate to develop a second flowsheet variant based on spiral operation. However the reduced amount of available ore did not permit investigating further upgrading of the rougher concentrate by spiral. Therefore in the second flowsheet the spiral rougher concentrate was ground and further upgraded by tabling.

For both flowsheets, the fine material, resulting from screening or regrinding the middlings, was processed on a slime deck table. The efficiency of tabling the fine ore was very low but the treatments are still included in the flowsheet to show the potential niobium extraction that can be achieved by gravity concentration methods. Detailed conditions and results of the tests are given in Appendix E.

Flowsheet 1: Table

The Flowsheet 1, Table concentration, is schematically presented in Fig. 14.

The flowsheet consisted of the following operating steps:

- Grinding the ore to -0.3 mm.
- Screening the ground ore on 0.074 mm sieve.
- Processing the -0.3 + 0.074 mm fraction on a sand deck table in two stages. In the rougher stage a rougher concentrate and a tailing (Tailing-1) were produced. The rougher concentrate was re-tabled and three products were collected. Concentrate 1, Concentrate 2 and Middling.
- Regrinding the Middling produced by the sand deck table to -0.074 mm.
- Compositing the reground Middling with -0.074 mm fraction resulting from grinding and screening the ore prior to tabling.
- Processing the fine ore (-0.074 mm) on a slime deck table. In the rougher stage two concentrates (Conc-3 and Conc-4) and a tailing (Tailing-2) were obtained. The tailing was re-treated on the same table and two Scavenger Concentrates and a Scavenger Tails were produced.

Flowsheet 2: Spiral and Table

The Flowsheet 2, spiral and table concentration, is presented in Fig. 15 and consisted of the following steps:

- Classifying the -1.7 mm crushed ore on 0.074 mm screen.
- Processing the -1.7 + 0.074 mm material by spiral, in one rougher stage and collecting a Rougher Concentrate, a Middling and a Final Tailing. In this flowsheet the Middling was not further processed.
- Regrinding the spirals rougher concentrate to -0.3 mm and classifying the ground material on 0.074 mm screen.

- Processing the -0.3 + 0.074 mm fraction on a sand deck table. In the first stage a high grade concentrate (C-1), a lower grade product (P-1) and a final coarse tailing (Tailing-1) were obtained. The product P-1 was re-tabled and a high grade concentrate (C-1), two middle grade concentrates (Conc-2, Conc-3) and a lower grade product (P-2) were collected. The high grade concentrates obtained in those two stages were combined and identified as Conc-1. The product P-2 was re-treated in the third table stage and finally one more concentrate (Conc-4) and two middling products (Midds-1 and Midds-2) were separated. The Concentrate-3 and Concentrate-4 were combined and identified as Concentrate 3 & 4.
- Regrinding the Table Middling Product M-1 to -0.074 mm.
- Compositing the reground Table Middling with the -0.074 mm fractions obtained from the initial screening of the ore and from screening the ground spiral rougher concentrate.
- Processing the fine material (-0.074 mm) on a slime deck table. In the first treatment a rougher concentrate and a fine tailing (Tailing-2) were obtained. The rougher concentrate was re-tabled and a Concentrate (Conc-5) and a Middling (Middling-3) were separated.

Selecting Optimum Flowsheet

The metallurgical results obtained by processing the niobium ore through Flowsheet 1 and 2 are given in Tables 15 and 16.

Flowsheet 1, Table concentration, produced a high grade concentrate of 16% Nb_2O_5 for a recovery in niobium of 50.5%. Flowsheet 2, spiral and table concentration yielded a high grade concentrate of 19.2% Nb_2O_5 for a recovery in niobium of 44.3%. Although the niobium recovery of Flowsheet 2 was lower than that of Flowsheet 1, the combined spiral-tabling process was selected to be used for further investigation to upgrade this niobium ore. The reasons for selecting Flowsheet 2 were:

- Spiral versus Table concentration present some economical advantages (higher capacity, less space, lower capital and operating costs).

- Spiral processing in the rougher stage, where approximately 3/4 of the ore is discarded as final tailing does not require grinding, therefore represents another economical advantage against the table.
- The niobium tied up in the spiral middling was not considered recoverable. However, by recirculating this middling to the spiral feed, with or without regrinding, it is estimated that at least half of the niobium contained in the product could be recovered in the spiral rougher concentrate.
- A conservative estimate of the niobium recovery in the spiral concentrate was used. There is a good possibility that this recovery can be improved by better adjustment of spiral operating conditions, by processing unclassified ore or even by using new kind of spiral equipment (ex. Reichert MK-VII Portless spiral).

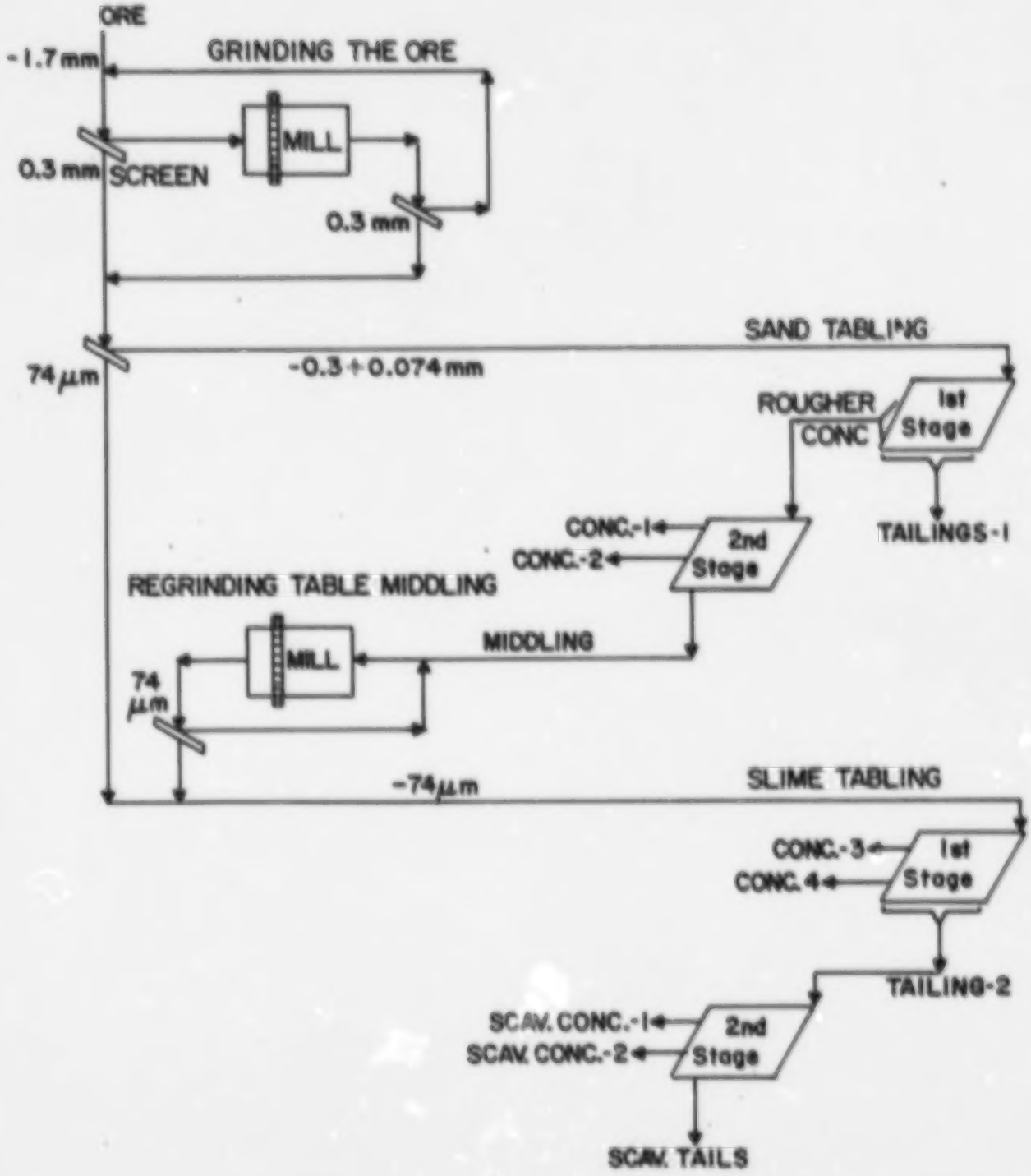

Fig. 14 Flowsheet 1 Laboratory table concentration

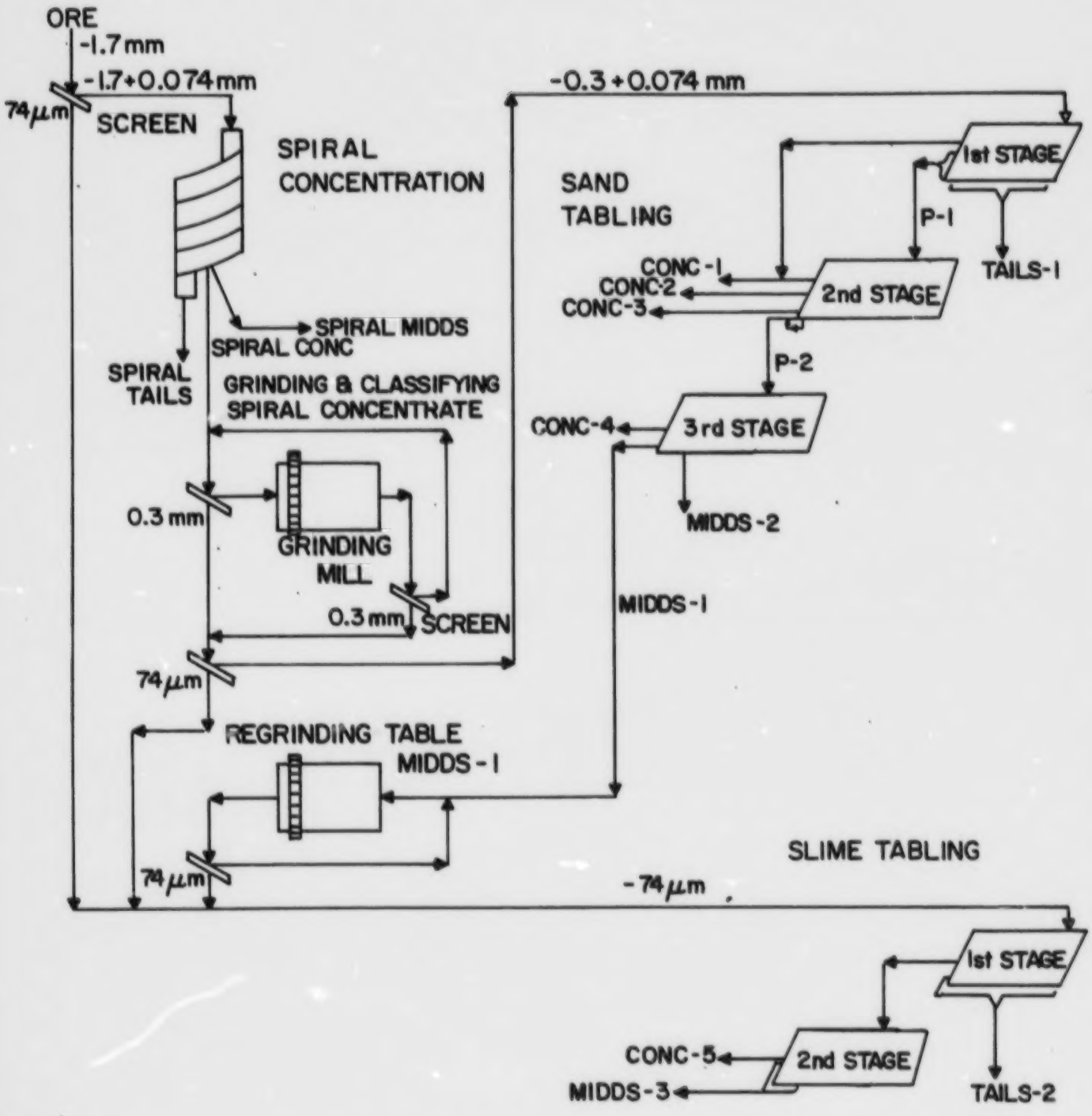

Fig. 15 Flowsheet 2.Laboratory spiral- table concentration

Table 15 - Table concentration (Flowsheet-1)

Process	Products	% Weight		Assay %	% Dist. Nb_2O_5	
		Ind.	O/A	Nb_2O_5	Ind.	O/A
Grind: -0.3 mm	Feed	100.0	100.0	0.50	100.0	100.0
Classification: 0.074 mm	Coarse (+0.074 mm)	65.6	65.6	0.48	62.9	62.9
	Fine (-0.074 mm)	34.4	34.4	0.54	37.1	37.1
	Head	100.0	65.6	0.48	100.0	62.9
	Conc-1	1.5	1.0	20.4	63.6	40.0
Sand Deck Table	Conc-2	0.5	0.3	5.64	5.9	3.7
	Middling	8.5	5.6	0.47	8.2	5.2
	Tailing	89.5	58.7	0.12	22.3	14.0
Composite Slime Deck	Head	100.0	40.0	0.53	100.0	42.3
Table Feed	Fine Ore	86.0	34.4	0.54	87.7	37.1
	Reground Midds	14.0	5.6	0.47	12.3	5.2
	Head	100.0	40.0	0.53	100.0	42.3
	Conc-3	0.5	0.2	14.7	13.9	5.9
	Conc-4	0.2	0.1	5.69	2.2	0.9
Slime Deck Table	Scav. Conc-1	0.7	0.3	2.42	3.2	1.3
	Scav. Conc-2	4.0	1.6	1.00	7.5	3.2
	Scav. Tails	94.6	37.8	0.41 (calc)	73.2	31.0
Total process	Final Conc (C1-4)		1.6	16.0		50.5

Table 16 - Spiral and Table concentration (Flowsheet-2)

Process	Products	% Weight		Assay %	% Dist. Nb_2O_5	
		Ind.	O/A	Nb_2O_5	Ind.	O/A
Grind: -1.7 mm	Feed	100.0	100.0	0.56	100.0	100.0
Classification: 0.074 mm	Coarse (+0.074 mm)	88.5	88.5	0.587	92.2	92.2
	Fine (-0.074 mm)	11.5	11.5	0.38	7.8	7.8
	Head	100.0	88.5	0.61	100.0	92.2
	Conc	24.1	21.3	1.81	71.2	65.6
Spiral	Middling	13.9	12.3	0.51	11.6	10.7
	Tailing	62.0	54.9	0.17	17.2	15.9
Grind Sp. Conc. -0.3 mm	Head	100.0	21.3	1.81	100.0	65.6
Classification: 0.074 mm	Coarse (+0.074 mm)	83.2	17.7	1.54	70.7	46.4
	Fine (-0.074 mm)	16.8	3.6	3.16	29.3	19.2
	Head	100.0	17.7	1.54	100.0	46.4
	Conc-1	3.0	0.5	30.0	58.4	27.1
	Conc-2	0.7	0.1	21.3	9.7	4.5
Sand Deck Table	Conc 3 & 4	1.7	0.3	9.5	10.5	4.9
	Middling-1	4.7	0.8	2.29	7.0	3.2
	Middling-2	28.5	5.1	0.48	8.9	4.1
	Tailing-1	61.4	10.9	0.14	5.5	2.6
	Head	100.0	15.9	1.11	100.0	30.2
Composite Slime Deck	Fine Ore	72.3	11.5	0.38	24.8	7.8
Table Feed	Fine Sp. Conc	22.7	3.6	3.16	64.8	19.2
	Reground Table M-1	5.0	0.8	2.29	10.4	3.2

Table 16 (Cont'd)

Process	Products	% Weight		Assay %	% Dist. Nb_2O_5	
		Ind.	O/A	Nb_2O_5	Ind.	O/A
	Head	100.0	15.9	1.17	100.0	30.2
	Conc-5	2.4	0.4	12.6	25.9	7.8
Slime Deck Table	Middling-3	4.3	0.7	1.72	6.3	1.9
	Tailing-2	93.3	14.8	0.85	67.8	20.5
Total process	Final Conc (C1-C5)		1.3	19.2		44.3

CPDU Test

The purpose of processing the niobium ore in CPDU (continuous development unit) was twofold:

a) Confirm, on a larger scale, the best results of laboratory gravity concentration tests.
b) Produce approximately 5 kg of niobium concentrate for further treatment.

Flowsheet

The technological flowsheet for processing the niobium ore in CPDU consisted in the following steps (Fig. 16):

- Crushing the ore to -1.7 mm.
- Classifying the crushed ore to remove the -0.074 mm fraction.
- Spiral concentration of the -1.7 + 0.074 mm fraction with middlings recirculation.
- Grinding the spiral concentrate to -0.3 mm, classifying the ground product on 0.074 mm screen and discarding the -0.074 mm fraction.
- Table concentration of the ground and classified spiral concentrate.

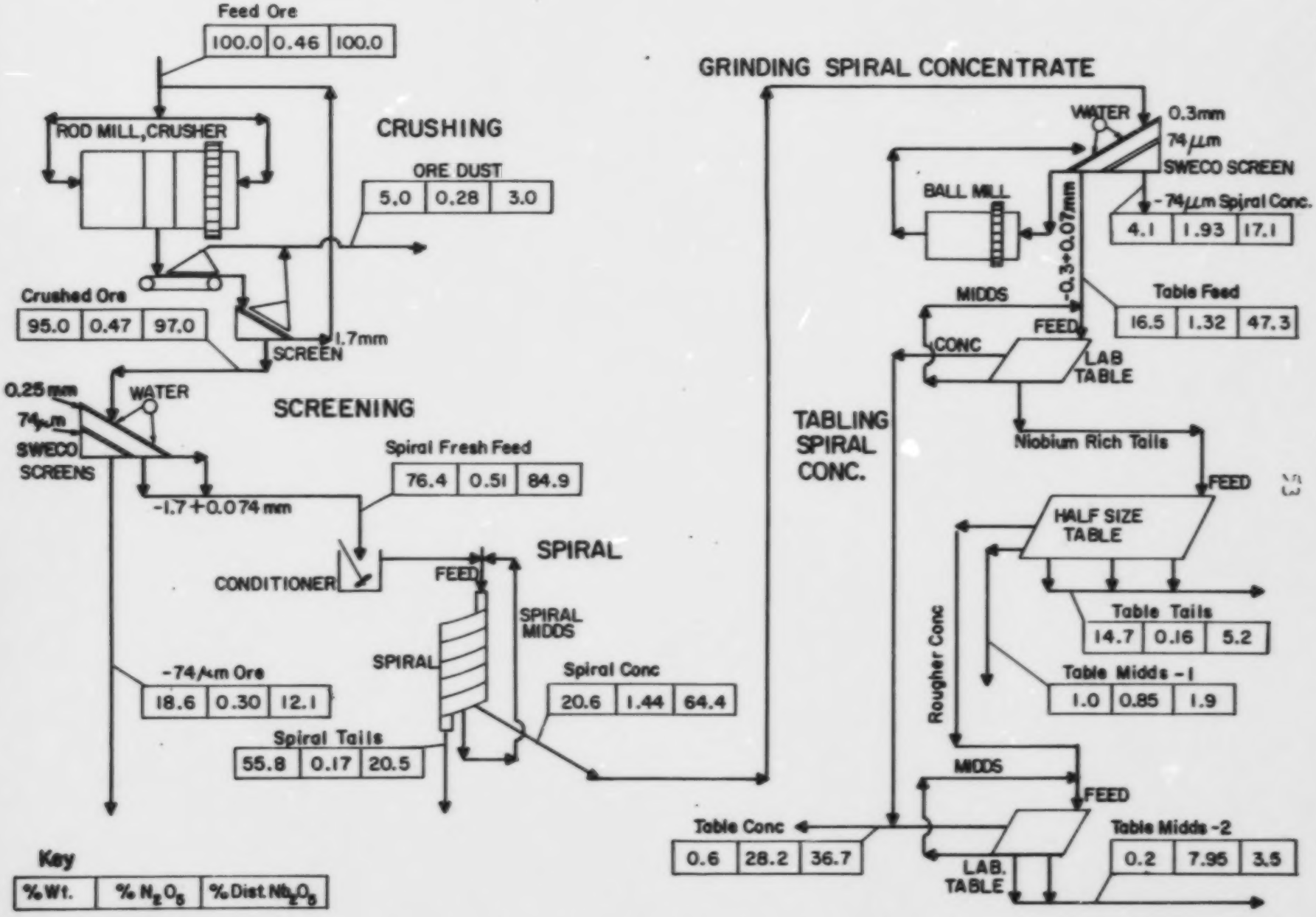

Fig. 16 Processing the niobium ore in CDM

Equipment Characteristics

The following pieces of equipment were used for the CPDU testwork:

- Crusher Marcy center peripheral discharge rod mill (61 x 183 mm) with 7.5 HP motor, Mill RPM:30, Rod charge 1.4 tonnes. Manufactured by the Mine and Smelter Supply Co., Denver, Colorado.
- Screen: Tyler, Ty-Rock vibrating screen 61 x 122 mm working in closed circuit with the rod mill crusher.
- Screen: Sweco, vibrating screens 762 mm and 610 mm diam, with 1/2 and 1/3 HP motor respectively, used to classify the crushed ore and the ground spiral concentrate.
- Belt feeder for spiral concentration; Belt width: 355 mm; Feeder volume: approx. 0.3 m^3; Motor: 1.5 HP; Manufactured by Renold U.K.
- Conditioner for spiral concentration; Diameter: 450 mm; Height: 600 mm; Motor: 0.5 HP; Manufactured by Denver.
- Spiral, 5-turn Humphreys spiral of cast iron with rubber liner. The pitch of the spiral was 337.5 mm (13 1/2 in.).
- Spiral Middlings Pump manufactured by Sala with a motor of 3 HP.
- Ball Mill for grinding the spiral concentrate, manufactured by Denver; Dimensions: 300 x 300 mm; Motor: 1 HP.
- Vibro Screw Feeder to feed the spiral concentrate to the grinding circuit; Max. RPM: 165; Min. RPM: 16.5; Motor: 1/3 HP.
- Conditioner in the grinding-classification circuit of the spiral concentrate; Diameter: 300 mm; Height: 300 mm; Motor: 1/2 HP.
- Pump in the grinding-classification circuit of the spiral concentrate. Manufactured by Sala with 3 HP motor.
- Conditioner to feed Laboratory Table; Diameter: 450 mm; Height: 600 mm; Motor: 3/4 HP.
- Pump to feed Laboratory Table; Manufactured by Robin Meyers, with 3/4 HP motor.
- Laboratory Deister Table; Length: 1250 mm; Width: 640 mm; S.P.M.: variable (104 used in most of the tests); Stroke: variable (12 mm used in most of the tests); Slope: 6-7°.

- Thickener to hold the niobium rich tailing of the first pass on the Laboratory Table; Manufactured by Dorr-Oliver; Diameter: 1.9 m; Height: 1.35 m; Motor: 1 HP.
- Conditioner to feed the Half Size Industrial Table; Manufactured by Dorr-Oliver; Diameter: 880 mm; Height: 1600 mm.
- Vertical Pump to feed the Half Size Table; Manufactured by Bodine Electric Company with 1/6 HP motor.
- Half Size Industrial Deister Table; Length: 2.5 m; Width: 1.37 m; Stroke: variable (12 mm used in the tests); S.P.M.: variable (132 used in the tests); Slope: 7°.

Process Description

The conditions and results of processing the niobium ore in CPDU are further described.

1. Crushing the ore to -0.074 mm

All the ore left after carrying out the laboratory testwork was crushed to -1.7 mm in the Marcy rod mill crusher.

A quantity of 1555.6 kg, -1.7 mm ore was used for the CPDU run. The dust produced by crushing the ore to -1.7 mm was retained in the dust collectors. It was estimated that 82.1 kg dust was generated by crushing the ore designated for CPDU.

The weight and niobium distributions in the crushed ore and dust product are given in Table 17.

Table 17 - Weight and niobium distribution in crushed ore

	Weight		Assay %	% Dist.
Product	kg	%	Nb_2O_5	Nb_2O_5
Head	1637.7	100.0	0.46	100.0
Ore -1.7 mm	1555.6	95.0	0.47	97.0
Dust	82.1	5.0	0.28	3.0

The size distributions of -1.7 mm crushed ore is given in Table 18.

Table 18 - Size distribution of crushed ore

Size		% Retained		% Pass.
Mesh	Micrometer	Ind.	Cum.	Cum.
+10	1700	2.8	2.8	97.2
28	600	29.7	32.5	67.5
35	425	15.0	47.5	52.5
48	300	9.0	56.5	43.5
60	250	5.9	62.4	37.6
100	150	10.9	73.3	26.7
150	106	6.0	79.3	20.7
200	74	5.0	84.3	15.7
270	53	3.0	87.3	12.7
400	38	3.3	90.6	9.4
-400		9.4	100.0	-
Total		100.0	-	-

The size distribution of the dust product is shown in Table 19.

Table 19 - Size distribution of the dust

	% Retained		% Pass.
Micrometer	Ind.	Cum.	Cum.
+125	0	0	100.0
88	3.4	3.4	96.6
62	5.0	8.4	91.6
44	6.7	15.1	84.9
31	9.6	24.7	75.3
22	12.0	36.7	63.3
16	11.0	47.7	52.3
11	11.8	59.5	40.5
7.8	10.7	70.2	29.8
5.5	7.3	77.5	22.5
3.9	7.9	85.4	14.6
2.8	6.8	92.2	7.8
-2.8	7.8	100.0	-
Total	100.0	-	-

2. Screening the -1.7 mm ore

The -1.7 mm crushed ore was classified prior to spiral processing to remove the -0.074 mm fraction.

The screening set-up consisted of a 0.25 mm screen and a double stage 0.074 mm sieves. The ore was pulped to about 20% solids and then pumped on the screens set. Additional water was used on the 0.25 mm screen and on the second 0.074 mm screening stage. The 0.25 mm screening was used to avoid overloading the fine screens and to obtain additional data for the size distribution of the -1.7 mm crushed ore.

After screening, the -1.7 + 0.25 mm and -0.25 + 0.074 mm products were sampled and then combined to form the spiral feed.

The -0.074 mm fraction was sampled and saved.

The equipment set-up for screening the crushed ore is given in Fig. 17.

The weight distribution and assay of the screening products are given in Table 20.

Table 20 - Weight and assay of screening products

Products	Weight kg	Weight %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Head (-1.7 mm ore)	1544.9	100.0	0.47	100.0
-1.7 + 0.25 mm	895.0	80.4	0.51	87.5
-0.25 + 0.074 mm	348.0			
-0.074 mm	301.9	19.6	0.30	12.5

The structure of the screening products is given in Table 21.

Table 21 - Structure of the screening products

Size		-1.7 + 0.25 mm			-0.25 + 0.074 mm			-1.7 + 0.074 mm (calc)			-0.074 mm		
		% Retained		% Pass.	% Retained		% Pass.	% Retained		% Pass.	% Retained		% Pass.
Mesh	µm	Ind.	Cum.	Cum.	Ind.	Cum.	Cum.	Ind.	Cum.	Cum.	Ind.	Cum.	Cum.
10	1700	4.6	4.6	95.4	-	-	100.0	3.3	3.3	96.7	-	-	100.0
28	600	52.9	57.5	42.5	-	-	100.0	38.1	41.4	58.6	-	-	100.0
35	425	18.2	75.7	34.3	-	-	100.0	13.1	54.5	45.5	-	-	100.0
48	300	12.4	88.1	11.9	0.1	0.1	99.9	9.0	63.5	36.5	-	-	100.0
60	250	7.4	95.5	4.5	0.2	0.3	99.7	5.4	68.9	31.1	-	-	100.0
100	150	3.5	99.0	1.0	37.2	37.5	62.5	12.9	81.8	18.2	1.2	1.2	98.8
150	106	0.2	99.2	0.8	27.9	65.4	34.6	7.9	89.7	10.3	0.8	2.0	98.0
200	74	0.1	99.3	0.7	26.9	92.3	7.7	7.6	97.3	2.7	1.0	3.0	97.0
270	53	0.1	99.4	0.6	6.5	98.8	1.2	1.9	99.2	0.8	10.2	13.2	86.8
400	38	0.1	99.5	0.5	0.7	99.5	0.5	0.3	99.5	0.5	20.8	34.0	66.0
-400		0.5	100.0	-	0.5	100.0	-	0.5	100.0	-	66.0	100.0	-
Total		100.0	-	-	100.0	-	-	100.0	-	-	100.0	-	-

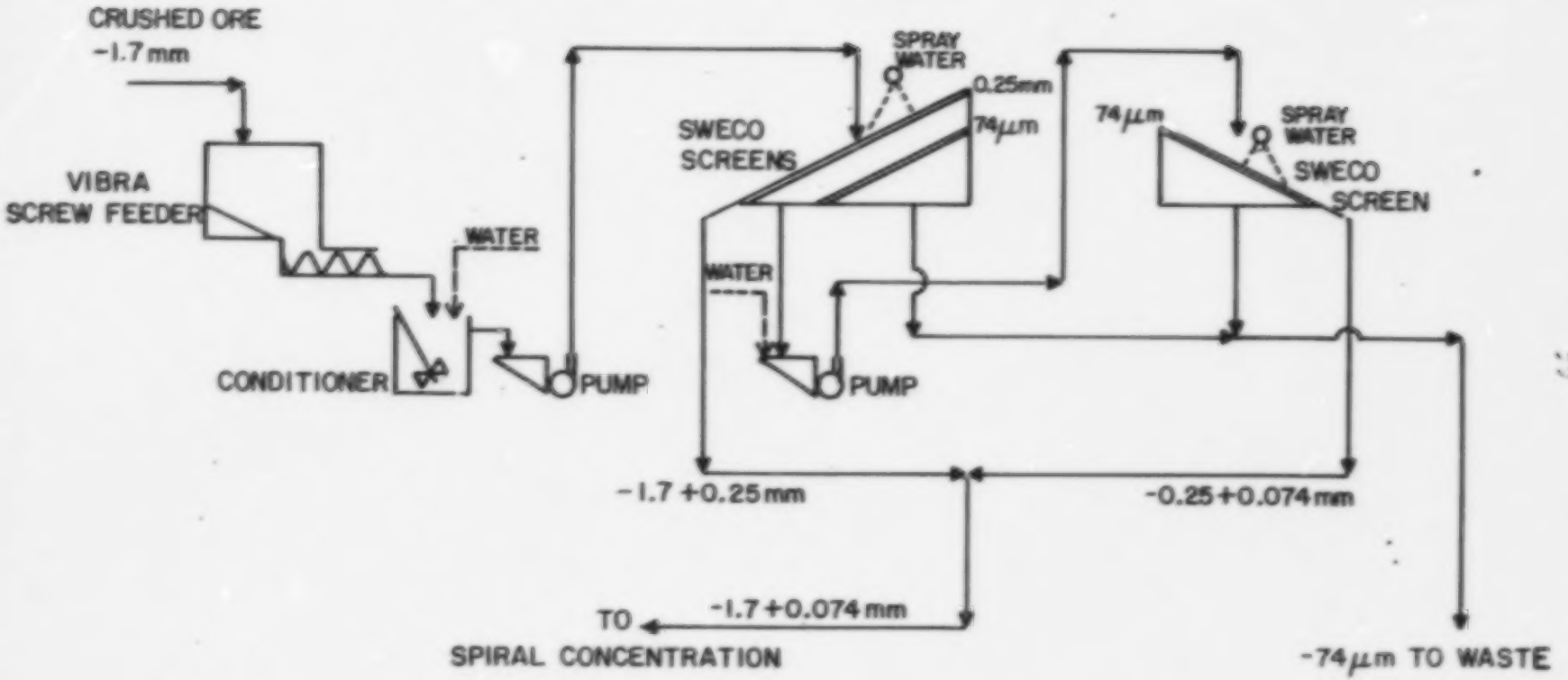

Fig. 17 Screening the crushed ore in CFDU

3. Spiral Concentration

The -1.7 + 0.074 mm ore was subjected to open circuit spiral concentration. The conditions for the CPDU runs were set based on the optimum results obtained in the batch closed circuit spiral tests. Few adjustments were made during the CPDU tests to accomodate the spiral process to open circuit conditions.

The equipment set-up for spiral concentration is given in Fig. 18.

The dry solids was fed by a belt feeder, at a rate of 1.8 t/h (30 kg/min) to a conditioner and pulped to 30% solids. The slurry leaving the conditioner and representing the Spiral Fresh Feed was discharged to a funnel. The middlings produced in the spiral process were recirculated to the same funnel and together with the fresh feed flowed by gravity to the spiral feed box forming the actual Spiral Feed.

The total load to the spiral was 1.9 t/h solids and the feed slurry volume was 86 L/min at a pulp density of 30% solids.

The total wash water addition was 37.1 L/min from which 30 L/min was added to the inlet of the wash water channel near the feed box and 7.1 L/min was supplied directly into the wash water channel near port #8.

Three products were obtained in the spiral process: a concentrate resulting from combined discharge of ports: 2, 4, 6 and 9, a middling collected as port #12 product and a tailing reporting in the tailing discharge box. The excess wash water was directed to the tailing pump.

The concentrate and the tailing were the actual final products of the spiral concentration. The middling was recirculated to the spiral feed; some make-up water was added to the middling pump.

Three spiral runs were carried out under almost similar conditions with the exception of the splitter settings which were adjusted to yield a concentrate of about 1.5% Nb_2O_5.

Table 22 gives the splitter settings of the three spiral runs.

During runs #1 and #2 which lasted 10 and 8.53 min, respectively, the spiral concentration results were roughly evaluated based on quick assays performed on grab samples taken during the tests. The final adjustments were then made for run #3 that lasted 21.8 min and during which a complete sampling of the spiral process was performed.

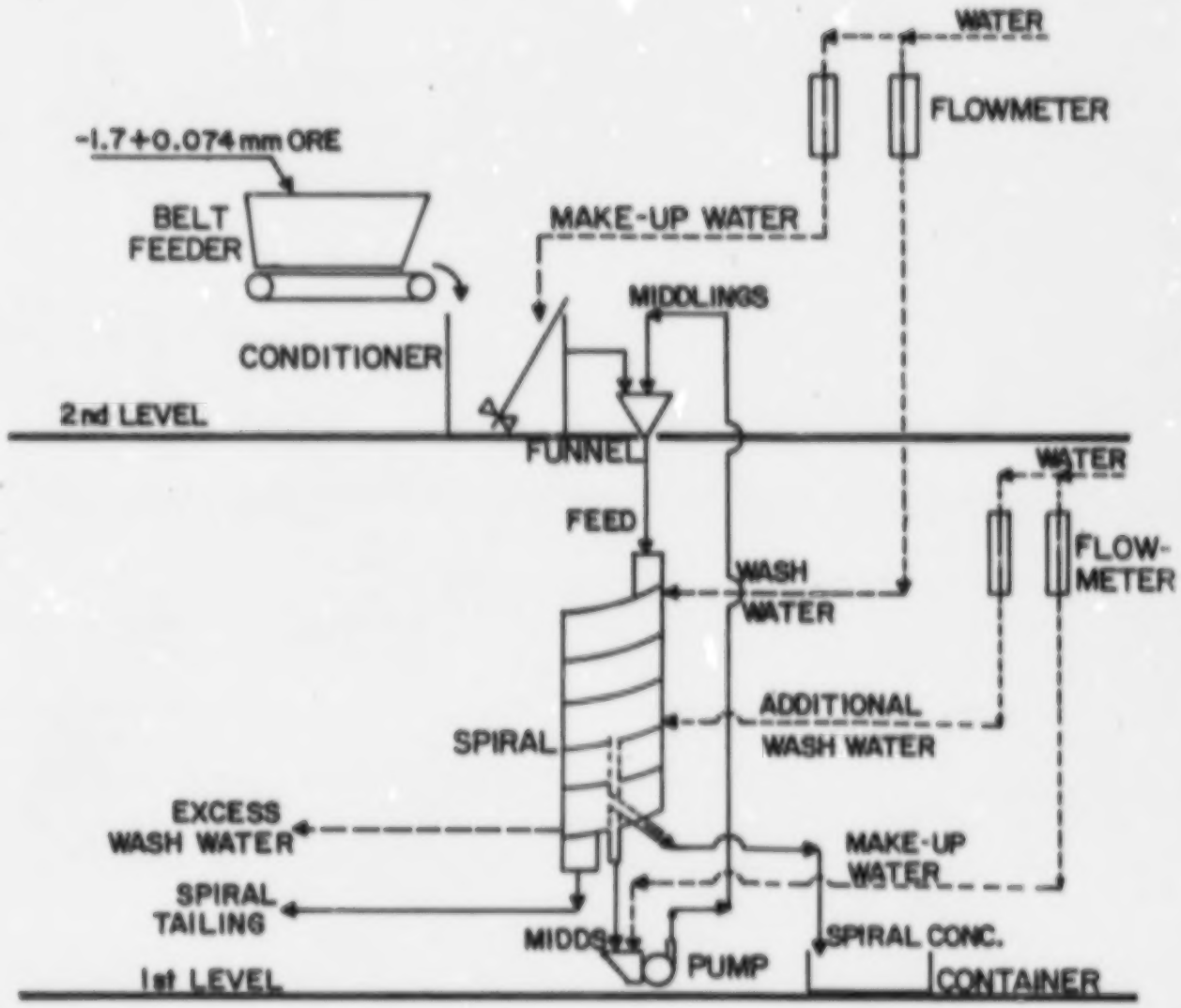

Fig. 18 Spiral concentration in CPDU

Table 22 - Splitter settings in CPDU Spiral tests

Port No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Setting Run #1	-	3	-	2	-	1	-	-	1	-	-	1	-	-	-
Setting Run #2	-	6	-	4	-	2	-	-	2	-	-	1	-	-	-
Setting Run #3	-	4	-	3	-	2	-	-	2	-	-	1	-	-	-
Product	-	C	-	C	-	C	-	-	C	-	-	M	-	-	-

C = Concentrate

M = Middling

The material balance of the CPDU spiral concentration is given in Table 23.

The metallurgical results of the CPDU spiral concentration were evaluated based on the following data:

- Weight of the dry solids fed to the spiral: 1215.2 kg.
- Weight and direct assay of the total concentrate collected from runs #1-3: 327.3 kg; 1.44% Nb_2O_5.
- Assay of the tailing sample collected during run #3: 0.17% Nb_2O_5.
- Assay of the middling sample collected during run #3: 0.83% Nb_2O_5.
- Calculated assay for Fresh Feed and Spiral Feed.

The results of spiral concentration are presented in Table 24.

The assay and weight of products obtained in the CPDU spiral runs are presented in Appendix F.

The screen analysis of spiral concentrate middling and tailings are given in Table 25.

Table 23 - Material balance of CPDU Spiral concentration

Product	Slurry				Solids			Water
	kg/min	% solids	S.G.	L/min		% Weight		L/min
					kg/min	Ind.	O/A	
Total solids and water to spiral	140.1	-	-	120.7	30.0	-	-	110.1
Fresh feed	100.0	30.0	1.24	80.6	30.0	-	100.0	70.0
Wash water	37.1	-	1.00	37.1	-	-	-	37.1
Midds make-up water	3.0	-	1.00	3.0	-	-	-	3.0
Spiral feed	106.5	29.6	1.24	86.1	31.5	100.0	105.0	75.0
Fresh feed	100.0	30.0	1.24	80.6	30.0	95.2	100.0	70.0
Concentrate	16.2	50.0	1.47	11.0	8.1	-	26.9	8.1
Middlings	6.5	23.3	1.17	5.5	1.5	4.8	5.0	5.0
Tailing	112.3	19.5	1.15	97.7	21.9	-	73.1	90.4
Excess wash water	11.6	-	1.00	11.6	-	-	-	11.6

Table 24 - Results of CPDU Spiral concentration

Product	Weight kg	Weight %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Spiral feed	1276.0	105.0	0.52	108.2
Fresh feed	1215.2	100.0	0.51	100.0
Concentrate	327.3	26.9	1.44	75.8
Middling	60.8	5.0	0.83	8.2
Tailing	887.9	73.1	0.17	24.2

Table 25 - Screen analysis of the CPDU Spiral products

Size		Concentrate			Middling			Tailing		
		% Retained		% Pass.	% Retained		% Pass.	% Retained		% Pass.
Mesh	µm	Ind.	Cum.	Cum.	Ind.	Cum.	Cum.	Ind.	Cum.	Cum.
+10	1700	0.7	0.7	99.3	0.6	0.6	99.4	3.2	3.2	96.8
28	600	10.5	11.2	88.8	2.2	2.8	97.2	42.1	45.3	54.7
35	425	14.8	26.0	74.0	7.7	10.5	89.5	16.1	61.4	38.6
48	300	13.3	39.3	60.7	8.6	19.1	80.9	9.4	70.8	29.2
60	250	11.5	50.8	49.2	8.0	27.1	72.9	5.3	76.1	23.9
100	150	22.8	73.6	26.4	27.7	54.8	45.2	9.4	85.5	14.5
150	106	13.2	86.8	13.2	21.4	76.2	23.8	5.4	90.9	9.1
200	74	9.3	96.1	3.9	17.7	93.9	6.1	5.2	96.1	3.9
270	53	2.2	98.3	1.7	4.8	98.7	1.3	2.3	98.4	1.6
400	38	0.2	98.5	1.5	0.5	99.2	0.6	0.4	98.8	1.2
-400		1.5	100.0	-	0.8	100.0	-	1.2	100.0	-
Total		100.0	-	-	100.0	-	-	100.0	-	-

Ind. - individual

Cum. - cumulative

4. Grinding and Classification of the Spiral Concentrate

The spiral concentrate was ground to -0.3 mm and classified on 0.074 mm screen in preparation for tabling.

The equipment set-up for grinding and classifying the spiral concentrate is showed in Fig. 19 and consisted mainly of a ball mill working in closed circuit with a screening set.

The dry spiral concentrate was fed by a Vibra Screw Feeder to a conditioner at a rate of about 60 kg/h, pulped to about 20% solids and pumped to a set of two Sweco screens: 0.3 and 0.074 mm openings. The +0.3 mm fraction was fed directly, by gravity, to the ball mill for regrinding, while the -0.3 + 0.074 mm and -0.074 mm fractions left the circuit. The ball mill discharge and the fresh concentrate were pumped back to the Sweco screens to continue the circuit.

The -0.3 + 0.074 mm fraction of the reground spiral concentrate represented the product that would further be upgraded by tabling.

The -0.074 mm fraction was stored and did not undergo any other treatment.

The grinding of the spiral concentrate was carried out at a low slurry density (30% solids in the mill discharge) to avoid over-grinding of the product. The grinding load was approximately 43 kg steel balls of 25 mm diam.

The weight distribution and assays of the products obtained by screening the ground spiral concentrate are given in Table 26.

Table 26 - Results of screening the reground Spiral concentrate

Product	Weight		Assay %	% Dist.
	kg	%	Nb_2O_5	Nb_2O_5
Head (Spiral Conc)	235.1	100.0	1.44	100.0
-0.3 + 0.074 mm	188.4	80.1	1.32	73.4
-0.074 mm	46.7	19.9	1.93	26.6

The screen analysis of the material in the main points of the grinding and classification circuit are presented in Table 27.

The screen analysis of the products leaving the grinding-classification circuit are given in Table 28.

Table 27 - Screen analysis of the products in the grinding-classification circuit of the spiral concentrate

Size		Screen feed			Mill feed			Mill Discharge		
Mesh	Micrometers	% Retained		% Pass.	% Retained		% Pass.	% Retained		% Pass.
		Ind.	Cum.	Cum.	Ind.	Cum.	Cum.	Ind.	Cum.	Cum.
+10	1700	0.7	0.7	99.3	1.1	1.1	98.9	0.2	0.2	99.8
28	600	6.4	7.1	92.9	14.4	15.5	84.5	2.2	2.4	97.6
35	425	10.9	18.0	82.0	23.9	39.4	60.6	6.0	8.4	91.6
48	300	12.9	30.9	69.1	29.3	68.7	31.3	11.4	19.8	80.2
60	250	11.8	42.7	57.3	23.7	92.4	7.6	11.9	31.7	68.3
100	150	22.2	64.9	35.1	6.6	99.0	1.0	15.1	46.8	53.2
150	106	12.6	77.5	22.5	0.2	99.2	0.8	8.5	55.3	44.7
200	74	10.0	87.5	12.5	0.1	99.3	0.7	8.6	63.9	36.1
270	53	3.4	90.9	9.1	0.1	99.4	0.6	5.0	68.9	31.1
400	38	2.2	93.1	6.9	0.1	99.5	0.5	6.8	75.7	24.3
-400		6.9	100.0	-	0.5	100.0	-	24.3	100.0	-
Total		100.0	-	-	100.0	-	-	100.0	-	-

Table 28 - Screen analysis of the final products of the grinding-classification circuit of the spiral concentrate

Size		-0.3 to 0.074 mm			-0.074 mm		
Mesh	Micrometer	% Retained		% Pass.	% Retained		% Pass.
		Ind.	Cum.	Cum.	Ind.	Cum.	Cum.
+35	425	0.1	0.1	99.9	-	-	100.0
48	300	0.1	0.2	99.8	-	-	100.0
60	250	4.9	5.1	94.9	0.2	0.2	99.8
100	150	40.0	45.1	54.9	2.8	3.0	97.0
150	106	25.9	71.0	29.0	2.3	5.3	94.7
200	74	22.4	93.4	6.6	2.1	7.4	92.6
270	53	5.4	98.8	1.2	7.8	15.2	84.8
400	38	0.7	99.5	0.5	18.9	34.1	65.9
-400		0.5	100.0	-	65.9	100.0	-
Total		100.0	-	-	100.0	-	-

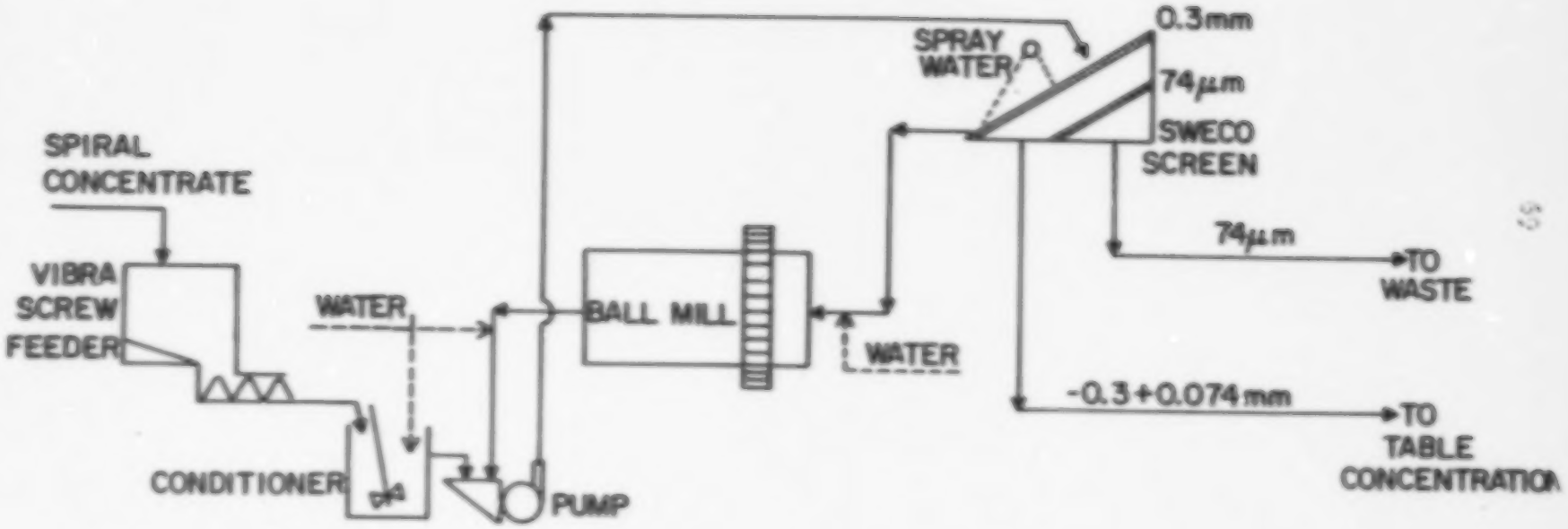

Fig. 19 Grinding and classifying the spiral concentrate in CPDU

5. Table Concentration

The reground and classified spiral concentrate was further upgraded by tabling.

The conditions for table concentration was chosen based on the optimum results obtained in the batch laboratory tests. First the spiral concentrate was processed on a small laboratory table but it became evident that the table was overloaded; a substantial amount of niobium reporting in the tailing. To reduce the feed rate of the table to the required amount for an efficient separation would have extended the table run for a long period of time. Therefore it was decided to process the entire quantity of spiral concentrate under these conditions and to collect the niobium rich tailing in a thickener. Then this tailing was reprocessed on a half-size industrial table whose concentrate was cleaned on a small laboratory table.

The equipment set-up for tabling concentration is given in Fig. 20.

The dry spiral concentrate was pulped in a conditioner at a slurry density of about 30% solids and then fed to the small laboratory table at a rate of approximately 3 L/min slurry or 1.1 kg/min solids.

The table was operated at a slope of 7°, 12 mm stroke and 104 S.P.M. The water addition was about 5 L/min.

A final, high grade niobium concentrate and a niobium rich tailing was continuously separated, while the middling product was recirculated to the feed.

The niobium rich tailing was discharged from the thickener, re-pulped in another conditioner to about 24% solids and fed to a half size table at a rate of 4 L/min slurry or 1.1 kg/min solids. This rate was arbitrarily chosen for this experiment and does not represent the optimum capacity of that table for treating the niobium ore.

The half-size table was operated at a slope of 7°, 12 mm stroke and 132 S.P.M. The water addition was about 12 L/min.

Three products were collected from the half-size table run: a rougher concentrate, a middling (Middling-1) and a final tailing. The last two products were not further processed.

The rougher concentrate was re-treated on the small laboratory table at a rate of about 0.2 kg/min solids and a slurry density of about 20% solids. A final concentrate and a tailing was continuously separated, while the middling product was recirculated to the table feed. This tailing was identified as Middling-2.

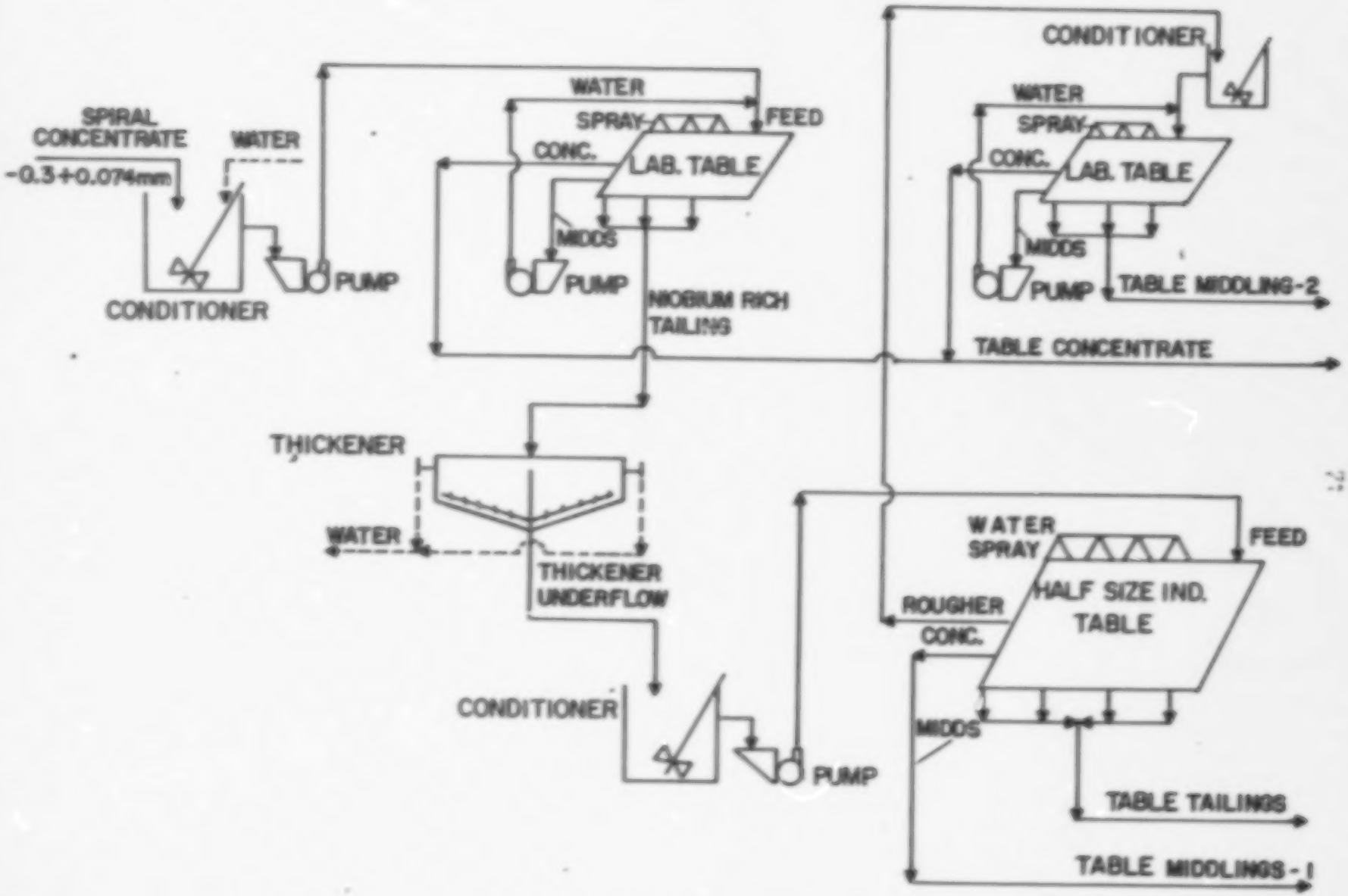

Fig. 20 Table concentration in CMDU

The final niobium concentrate obtained in the first treatment on the small table was identified as Table Concentrate A and the final niobium concentrate obtained on the second treatment on the small laboratory table was identified as Table Concentrate B. Concentrates A and B were combined and this composite represented the Final Table Concentrate.

The metallurgical results of the table concentration are given in Table 29.

Table 29 - Table metallurgical results

Product	Weight kg	Weight %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Head (Spiral Conc)	188.375	100.0	1.32	100.0
Concentrate A	2.665	1.4	32.3	35.4
Concentrate B	3.954	2.1	25.6	42.1
Final Concentrate (A&B)	6.619	3.5	28.2	77.5
Middling-2	2.296	1.2	7.95	7.4
Middling-1	11.139	5.9	0.85	4.1
Tailing	168.321	89.4	0.16	11.0

The screen analysis of the tabling products are given in Table 30.

Table 30 - Sieve analysis of the Tabling products

Size		Final concentrate			Middling-1			Middling-2			Tailing		
Mesh	Micrometers	% Retained		% Pass.	% Retained		% Pass.	% Retained		% Pass.	% Retained		% Pass
		Ind.	Cum.	Cum.	Ind.	Cum.	Cum.	Ind.	Cum.	Cum.	Ind.	Cum.	Cum.
+28	600	-	-	100.0	-	-	100.0	0.2	0.2	99.8	-	-	100.0
35	425	-	-	100.0	-	-	100.0	0.5	0.7	99.3	-	-	100.0
48	300	0.3	0.3	99.7	0.1	0.1	99.9	0.2	0.9	99.1	0.1	0.1	99.9
60	250	1.9	2.2	97.8	0.3	0.4	99.6	6.2	7.1	92.9	4.2	4.3	95.7
100	150	27.8	30.0	70.0	6.0	6.4	93.6	25.5	32.6	67.4	45.6	49.9	50.1
150	106	26.0	56.0	44.0	16.9	23.3	76.7	6.3	38.9	61.1	26.8	76.7	23.3
200	74	33.7	89.7	10.3	54.4	77.7	22.3	36.5	75.4	24.6	17.4	94.1	5.9
270	53	9.0	98.7	1.3	18.4	96.1	3.9	19.5	94.9	5.1	4.2	98.3	1.7
400	38	1.3	100.0	-	3.2	99.3	0.7	3.7	98.6	1.4	0.9	99.2	0.8
-400		-	100.0	-	0.7	100.0	-	1.4	100.0	-	0.8	100.0	-
Total		100.0	-	-	100.0	-	-	100.0	-	-	100.0	-	-

Total Process Evaluation

The metallurgical results of the entire process carried out to upgrade the niobium ore in CPDU are presented in Table 31.

The results of the CPDU test showed that by applying a gravity concentration process consisting of spiral and tabling, a final niobium concentrate of 28.2% Nb_2O_5 was obtained at a weight yield of 0.6% and a niobium recovery of 36.7%, both related to the head sample.

The major niobium losses were reported in the following products:

a) The -0.074 mm fraction obtained from screening the crushed ore (12.1%)
b) The -0.074 mm fraction obtained from screening the ground Spiral Concentrate (17.1%)
c) Spiral Tailing (20.5%)

Minor niobium losses were reported in the Table Middlings (5.4%), Table Tailing (5.2%) and Ore Dust (3.0%).

Little can be done to avoid the niobium losses in the -0.074 mm fractions under the gravity concentration concept. Other methods of concentration should be considered to investigate the possibility of niobium extraction from the fine material.

Besides these unavoidable losses, the spiral and table process has rejected products, relatively coarse sized, that were responsible for a substantial niobium loss.

To analyse the sources of niobium losses, the spiral and table products were subjected to heavy liquid determinations and microscopic examination of polished section.

The results of the microscopic examination are reported separately in the same paper that presents the mineralogical investigation of the ore sample.

The results of the heavy liquid determinations are presented in Table 32, based on which the following comments can be made:

Table 31 - Metallurgical results of CPDU test

Process	Product	Weight kg	Weight % Ind.	Weight % O/A	Assay % Nb_2O_5	% Dist. Ind.	% Dist. O/A
Crushing to -1.7 mm	Head sample	1637.700	100.0	100.0	0.46	100.0	100.0
	-1.7 mm ore	1555.600	95.0	95.0	0.47	97.0	97.0
	Dust	82.100	5.0	5.0	0.28	3.0	3.0
Screening -1.7 mm ore on 0.25 and 0.074 mm	Head (-1.7 mm)	1548.900	100.0	95.0	0.47	100.0	97.0
	-1.7 + 0.25 mm	895.000	80.4	76.4	0.51	87.5	84.9
	-0.2 + 0.074 mm	348.000					
	-0.074 mm	301.900	19.6	18.6	0.30	12.5	12.1
Spiral concentration	Head (-1.7 mm + 0.074 mm)	1215.200	100.0	76.4	0.51	100.0	84.9
	Spiral Conc	327.300	26.9	20.6	1.48	75.8	64.4
	Spiral tailing	887.900	73.1	55.8	0.17	24.2	20.5
Grinding Sp. Conc to -0.3 mm and classification on 74 µm	Head (Sp. Conc)	235.100	100.0	20.6	1.48	100.0	64.4
	Table Conc	6.619	3.5	0.6	28.2	77.5	36.7
	Table Midds-2	2.296	1.2	0.2	7.95	7.8	3.5
	Table Midds-1	11.139	5.9	1.0	0.85	4.1	1.9
	Table tailing	168.321	89.4	14.7	0.16	11.0	5.2
Tabling Sp. Conc	Head (-0.3 + 0.074 mm)	188.375	100.0	16.5	1.32	100.0	47.3
	Table Conc	6.619	3.5	0.6	28.2	77.5	36.7
	Table Midds-2	2.296	1.2	0.2	7.95	7.8	3.5
	Table Midds-1	11.139	5.9	1.0	0.85	4.1	1.9
	Table tailing	168.321	89.4	13.7	0.16	11.0	5.2

Table°32 - Results of heavy liquid determinations for spiral and tabling products

Process product	Heavy liquid product	Weight %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Spiral	Head	100.0	1.35	100.0
Conc	Sink	4.1	30.9	93.6
	Float	95.9	0.09	6.4
Spiral	Head	100.0	0.53	100.0
Middling	Sink	1.6	27.8	83.4
	Float	98.4	0.09	16.6
Spiral	Head	100.0	0.16	100.0
Tailing	Sink	0.3	24.8	45.3
	Float	99.7	0.09	54.7
Table	Head	100.0	27.3	100.0
Conc	Sink	78.0	34.6	99.0
	Float	22.0	1.24	1.0
Table	Head	100.0	8.01	100.0
Middling-2	Sink	28.6	26.7	95.3
	Float	71.4	0.53	4.7
Table	Head	100.0	0.74	100.0
Middling-1	Sink	2.5	23.3	78.9
	Float	97.5	0.16	21.1
Table	Head	100.0	0.17	100.0
Tailing	Sink	0.3	26.9	47.4
	Float	99.7	0.09	52.6

Spiral Concentration. All the products: Concentrate, Middling and Tailing showed good liberation of the niobium minerals. The sink products had a relatively high niobium content while the Nb_2O_5 assay of the floats were very low. It appeared that a substantial amount of liberated gangue minerals reported in the concentrate and a significant quantity of liberated niobium minerals were washed down in the tailing. To improve the efficiency of the minerals separation a better adjustment of the spiral operating conditions could be tried

(wash water addition, ports and splitter setting, etc.). Also other types of gravity concentration equipment can be experimented with during this stage.

An important conclusion that can be drawn from these determinations is that the niobium minerals in the -1.7 + 0.074 mm size range are liberated well enough to permit the producing, by gravity methods, of a concentrate of about 25-30% Nb_2O_5 without any regrinding of the products. This means that the rougher concentrate obtained in the first stage can be further cleaned in a number of consecutive stages without grinding and screening, thus avoiding the niobium loss in the -0.074 mm fraction. Whether this upgrading can be practically achieved by spiral or other type of gravity concentration equipment is a matter of trial.

Table Concentration. In the table treatment the particles size range was finer (-0.3 + 0.074 mm) than in the spiral process but the level of concentration was much higher. That is why the float products of the Concentrate and Middlings had relatively high niobium content indicating the presence of some locked particles (niobium minerals and gangue). What kind of gangue minerals were associated with the niobium carrier and to what extent will be revealed by the microscopic examination of the products polished sections.

The Table Tailing exhibited good liberation of the niobium minerals demonstrated by the low content of the float and relatively high grade of the sink products.

The tabling performance can be improved by regrinding the middlings before recirculating them on the table, to liberate the niobium present in the locked particles. Also better adjustment of table operating conditions could reduce the amount of liberated niobium washed in the tailing. However, it should be noted that the niobium losses in the tabling treatment were relatively minor and therefore the expenses for important modification in the table circuit (regrinding, classifying) might not be entirely justified by the gain in the niobium extraction.

The chemical composition of the final niobium concentrate is given in Table 33.

Table 33 - Chemical composition of the final concentrate

Nb_2O_5	Fe_2O_3	P_2O_5	S	CaO	Al_2O_3	TiO_2	SiO_2	Ta_2O_5	Th	U	L.O.I.
%	%	%	%	%	%	%	%	%	%	%	%
28.2	13.0	0.66	3.01	10.7	0.19	0.95	1.23	0.1	1.18	0.0003	5.79

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Acknowledgement is finally extended to J.D. MacLeod for his very fine drafting work.

APPENDIX A

JIG AND TABLE
CONDITIONS AND RESULTS OF THE TESTS

JIG TEST REPORT

DATE: 2/11/83

TEST: J-1

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Steel shots, 2 layers 6-7 mm, 892 g.
Also natural bed 3.35 - 2.36 mm (6-8 mesh) up to 25 mm to the top.

STROKE: 6 mm (1/4")

SPEED: 700 rpm (80 setting)

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 6.3 L/min

WASH (TOP): 7.5 L/min

REMARKS

Operating time: 15'; Natural bed rejected by machine: 469 g.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1973.4	7.2	2.29	29.5
Tails	25,537.5	92.8	0.425	70.5
Head	27,510.9	100.0	0.559	100.0

JIG TEST REPORT

DATE: 3/11/83

TEST: J-2

Same as #1 except reduced feed rate.

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Steel shots, 2 layers 6-7 mm, 892 g. Also natural bed 3.35 - 2.36 mm (6-8 mesh).

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10 + 60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 6.3 L/min

WASH (TOP): 7.5 L/min

REMARKS

Operating time: 15'; Natural bed rejected by machine: 302.2 g. Separation not selective, too much weight reported to the concentrate.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	5284.1	35.5		
Tails	9602.7	64.5	No assay	
Head	14,886.8	100.0		

JIG TEST REPORT

DATE: 3/11/83

TEST: J-3

Same as #2 except added more shots.

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Added 1536.5 g steel shots same size as in the test J-1. Total shots 2428.5 g. Little natural bed left from previous tests.

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 6.3 L/min

WASH (TOP): 7.5 L/min

REMARKS

Separation not selective.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	3475.4	22.1		
Tails	12,236.9	77.0	No assay	
Head	15,712.3	100.0		

JIG TEST REPORT

DATE: 7/11/83

TEST: J-4

Same as #3 except increased feed rate and increased wash water.

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 2428.5 g

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 6.3 L/min

WASH (TOP): 15 L/min

REMARKS

Operating time: 10'. Separation not selective.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Cone	2370.5	11.5		
Tails	18,160.0	88.5	No assay	
Head	20,530.5	100.0		

JIG TEST REPORT

DATE: 7/11/83

TEST: J-5
Same as #4 except increased dilution water.

CONDITIONS

SCREEN: 4.75 mm (4 mesh)
BEDDING MATERIAL: Shots, 6-7 mm, 2428.5 g
STROKE: 6 mm (1/4")
SPEED: 600 rpm

FEED
SIZE: -1.7 + 0.25 mm (-10+60 mesh)
RATE: 120 kg/h

WATER
DILUTION (SIDE): 15 L/min
WASH (TOP): 15 L/min

REMARKS
Separation improved.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1034.5	4.3	2.39	18.0
Tails	23,041.0	95.7	0.49	82.0
Head	24,075.5	100.0	0.572	100.0

JIG TEST REPORT

DATE: 8/11/83

TEST: J-6

Replaced screen and shots.

Increased dilution and wash water.

CONDITIONS

SCREEN: 2.36 mm (8 mesh)

BEDDING MATERIAL: Shots, 3-5 mm (1/8 - 3/16")

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 20 L/min

WASH (TOP): 20 L/min

REMARKS

Good separation. Concentrate weight reduced; many black particles falling in the hutch.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	378.6	1.5	5.76	15.7
Tails	24,062.0	98.5	0.47	84.3
Head	24,440.6	100.0	0.549	100.0

JIG TEST REPORT

DATE: 9/11/83

TEST: J-7

Same as #6 except reduced stroke.

CONDITIONS

SCREEN: 2.36 mm (8 mesh)

REDOING MATERIAL: Shots, 3-5 mm (1/8 ~ 3/16")

STROKE: 4.7 mm (3/16")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 20 L/min

WASH (TOP): 20 L/min

REMARKS

Good separation. Apparently more weight reported in the hutch.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	519.0	2.5	4.75	20.9
Tails	20,186.0	97.5	0.46	79.1
Head	20,705.0	100.0	0.567	100.0

JIG TEST REPORT

DATE: 21/11/83

TEST: J-8

Same as #7 except reduced stroke and less water. A little 1/2" board installed on the jig O/F.

CONDITIONS

SCREEN: 2.36 mm (8 mesh)

BEDDING MATERIAL: Shots, 3-5 mm (1/8 - 3/16")

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 6.3 L/min

WASH (TOP): 7.5 L/min

REMARKS

Little conc recovered. Many black minerals noticed in the tails.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	667.6	1.7	4.52	15.1
Tails	37,682.0	98.3	0.44	84.9
Head	38,349.6	100.0	0.509	100.0

JIG TEST REPORT

DATE: 21/11/83

TEST: J-9

CONDITIONS

SCREEN: 2.36 mm (8 mesh)

BEDDING MATERIAL: Shots, 3-5 mm (1/8 - //16")

STROKE: (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 6.3 L/min

WASH (TOP): 7.5 L/min

REMARKS

Quantity of concentrate increased as compared with Test #8 but still many black minerals in the tails. Found agglomerated shots. Hutch product finer size than the tails. Test cancelled.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5

JIG TEST REPORT

DATE: 22/11/83

TEST: J-10
Changed screen.

CONDITIONS

SCREEN: 4.75 mm (4 mesh)
BEDDING MATERIAL: 2 layers of shots, 6-7 mm, 890 g
STROKE: 6 mm (1/4")
SPEED: 600 rpm

FEED
SIZE: -1.7 + 0.25 mm (-10+60 mesh)
RATE: 120 kg/h

WATER
DILUTION (SIDE): 15 L/min
WASH (TOP): 15 L/min

REMARKS

Removed 1/2" board on O/F; Poor separation. Split ~50/50 between concentrate and tails.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
			No assay	

JIG TEST REPORT

DATE: 23/11/83

TEST: J-11

Increased amount of shots. Also decreased wash water rate.

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 15 L/min

WASH (TOP): 12 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1656.8	10.0	1.97	36.6
Tails	14,868.5	90.0	0.38	63.4
Head	16,525.3	100.0	0.539	100.0

JIG TEST REPORT

DATE: 23/11/83

TEST: J-12

Reduced dilution water rate.

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 8.6 L/min

WASH (TOP): 12 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1526.1	6.3	2.82	28.3
Tails	22,813.5	93.7	0.48	71.7
Head	24,339.6	100.0	0.627	100.0

JIG TEST REPORT

DATE: 23/11/83

TEST: J-13

Reduced both dilution and wash water rates.

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 6.3 L/min

WASH (TOP): 10 L/min

REMARKS

Test cancelled. Too much concentrate drawn in the hutch.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5

JIG TEST REPORT

DATE: 23/11/83

TEST: J-14

Increased dilution water rate.

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 7.5 L/min

WASH (TOP): 10 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	4335.1	21.7	1.37	52.0
Tails	14,663.0	78.3	0.35	48.0
Head	19,998.1	100.0	0.571	100.0

JIG TEST REPORT

DATE: 11/06/84

TEST: J-18

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 15 L/min

WASH (TOP): 7.5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1764.0	15.7	0.92	31.6
Tails	9474.9	84.3	0.37	68.4
Head	11,238.9	100.0	0.46	100.0

JIG TEST REPORT

DATE: 12/06/84

TEST: J-19

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 20 L/min

WASH (TOP): 15 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	700.1	6.6	1.82	28.0
Tails	9904.1	93.4	0.33	72.0
Head	10,604.2	100.0	0.43	100.0

JIG TEST REPORT

DATE: 12/06/84

TEST: J-20

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 1.5 L/min

WASH (TOP): 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	4043.7	38.6	7.14	75.7
Tails	6432.3	61.4	0.23	24.3
Head	10,476.0	100.0	0.58	100.0

JIG TEST REPORT

DATE: 13/06/84

TEST: J-21

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 15 L/min

WASH (TOP): 7.5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	3112.0	28.5	1.11	67.8
Tails	7817.7	71.5	0.21	32.2
Head	10,929.7	100.0	0.47	100.0

JIG TEST REPORT

DATE: 13/06/84

TEST: J-22

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.25 mm (-10+60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 20 L/min

WASH (TOP): 15 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1717.7	21.0	1.42	61.1
Tails	6478.1	79.0	0.24	38.9
Heads (calc)	8195.8	100.0	0.49	100.0

TABLE TEST REPORT

DATE: 3/11/83

TEST: T-1

CONDITIONS

DECK: Sand

SLOPE: 7°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.25 + 0.074 mm (-60+200 mesh)

CHARGE: 2 kg

WATER: 5 L/min

REMARKS

Conc 1 and Conc 2 retreated to obtain cleaner concentrate and cleaner tails of each.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Cl. Conc-1	22.2	1.1	16.3	39.2
Cl. Tails-1	80.9	3.9	2.20	18.7
Cl. Conc-2	10.9	0.5	3.41	3.7
Cl. Tails-2	176.2	8.4	0.392	7.2
Tails	1799.0	86.1	0.166	31.2
Head	2089.2	100.0	0.458	100.0
Ro Conc		13.9	2.267	68.8

TABLE TEST REPORT

DATE: 9/11/83

TEST: T-2

CONDITIONS

DECK: Sand

SLOPE: 7°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.25 + 0.074 mm (-60+200 mesh)

CHARGE: 2 kg

WATER: 5 L/min

REMARKS

Same as Test #1 except only one concentrate and a tailing was collected while middlings have been recirculated to the feed.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	50.2	1.8	11.5	46.8
Tails	2746.7	98.2	0.24	53.2
Head	2796.9	100.0	0.443	100.0

TABLE TEST REPORT

DATE: 17/11/83

TEST: T-3

CONDITIONS

DECK: Sand

SLOPE: 7°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.25 + 0.074 mm (-60+200 mesh)

CHARGE: 2 kg

WATER: 5 L/min

REMARKS

Same as Test #2 (Middlings recirculation) except a concentrate of higher grade was collected.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	40.3	1.3	16.4	44.4
Tails	3080.4	98.7	0.27	55.6
Head	3120.7	100.0	0.48	100.0

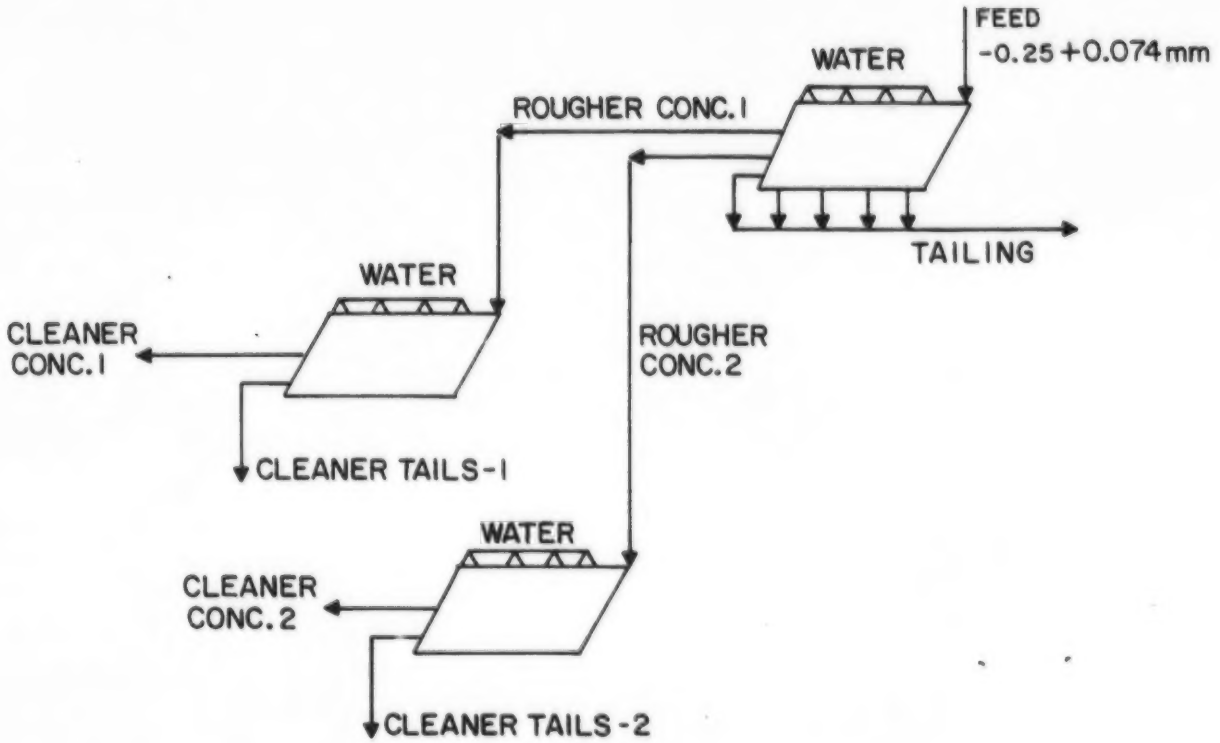

Fig. T-1 Scheme of table test T-1

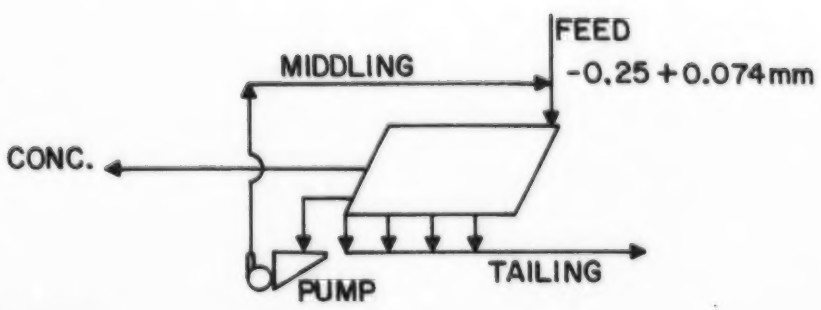

Fig. T-2 Scheme of table tests T-2 and T-3

APPENDIX B

COARSE JIG, FINE JIG AND TABLE CONDITIONS AND RESULTS OF THE TESTS

COARSE JIG TEST REPORT

DATE: 6/12/83

TEST: J-15

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.6 mm (-10+28 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 15 L/min

WASH (TOP): 7.5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1929.8	22.4	1.32	66.7
Tails	6671.3	77.6	0.19	33.3
Head	8601.1	100.0	0.443	100.0

COARSE JIG TEST REPORT

DATE: 6/12/83

TEST: J-16

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.6 mm (-10+28 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 15 L/min

WASH (TOP): 10 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	2624.9	11.9	2.47	53.5
Tails	19,522.0	88.1	0.29	46.5
Head	22,146.9	100.0	0.55	100.0

COARSE JIG TEST REPORT

DATE: 7/12/83

TEST: J-17

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.6 mm (-10+28 mesh)

RATE: 120 kg/h

WATER

DILUTION (SIDE): 6.3 L/min

WASH (TOP): 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	2554.1	8.9	2.23	37.1
Tails	26,048.0	91.1	0.37	62.9
Head	28,602.1	100.0	0.536	100.0

COARSE JIG TEST REPORT

DATE: 14/06/84

TEST: J-23

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 6 mm (1/4")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.6 mm (-10+28 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 20 L/min

WASH (TOP): 15 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1304.9	14.6	2.33	58.7
Tails	7611.9	85.4	0.28	41.3
Head	8916.8	100.0	0.58	100.0

COARSE JIG TEST REPORT

DATE: 14/06/84

TEST: J-24

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.6 mm (-10+28 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 15 L/min

WASH (TOP): 7.5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	347.5	4.0	4.63	41.7
Tails	8316.2	96.0	0.27	58.3
Head	8663.7	100.0	0.44	100.0

COARSE JIG TEST REPORT

DATE: 18/06/84

TEST: J-25

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -1.7 + 0.6 mm (-10+28 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 8.6 L/min

WASH (TOP): 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1227.0	14.7	2.46	52.1
Tails	7130.7	85.3	0.39	47.9
Head (calc)	8357.7	100.0	0.64	100.0

FINE JIG TEST REPORT

DATE: 18/06/84

TEST: J-26

CONDITIONS

SCREEN: 4.75 mm (4 mesh)

BEDDING MATERIAL: Shots, 6-7 mm, 1800 g

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -0.6 + 0.20 mm (-28+60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 20 L/min

WASH (TOP): 7.5 L/min

REMARKS

Too much concentrate going in the hutch, need to change screen.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	3267.8	47.7		
Tails	3581.6	52.3	CANCELLED	
Head (calc)	6849.4	100.0		

FINE JIG TEST REPORT

DATE: 19/06/84

TEST: J-27

CONDITIONS

SCREEN: 2.36 mm (8 mesh)

BEDDING MATERIAL: Shots, 3-5 mm, 1695 g

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -0.6 + 0.20 mm (-28+60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 20 L/min

WASH (TOP): 7.5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1035.6	10.6	1.88	41.8
Tails	8716.8	89.4	0.31	58.2
Head (calc)	9752.4	100.0	0.48	100.0

FINE JIG TEST REPORT

DATE: 19/06/84

TEST: J-28

CONDITIONS

SCREEN: 2.36 mm (8 mesh)

BEDDING MATERIAL: Shots, 3-5 mm, 1695 g

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -0.6 + 0.20 mm (-28+60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 8.6 L/min

WASH (TOP): 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	3181.3	37.5		
Tails	5295.5	62.5	CANCELLED	
Head (calc)	8476.8	100.0		

FINE JIG TEST REPORT

DATE: 20/06/84

TEST: J-29

CONDITIONS

SCREEN: 2.36 mm (8 mesh)

BEDDING MATERIAL: Shots, 3-5 mm, 1695 g

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -0.6 + 0.20 mm (-28+60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 15 L/min

WASH (TOP): 7.5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1563.8	18.1	1.41	48.6
Tails	7068.9	81.9	0.33	51.4
Head (calc)	8632.7	100.0	0.53	100.0

FINE JIG TEST REPORT

DATE: 21/06/84

TEST: J-30

CONDITIONS

SCREEN: 2.36 mm (8 mesh)

BEDDING MATERIAL: Shots, 3-5 mm, 1695 g

STROKE: 3 mm (1/8")

SPEED: 600 rpm

FEED

SIZE: -0.6 + 0.20 mm (-28+60 mesh)

RATE: 60 kg/h

WATER

DILUTION (SIDE): 20 L/min

WASH (TOP): 15 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	319.5	4.3	3.89	32.1
Tails	7133.9	95.7	0.37	67.9
Head (calc)	7453.4	100.0	0.52	100.0

TABLE TEST REPORT

DATE: 7/12/83

TEST: T-4

CONDITIONS

DECK: Sand

SLOPE: 7°

STROKE: 12 mm

S.P.M: 155 and 104

FEED

SIZE: -0.6 + 0.25 mm (-28+60 mesh)

CHARGE: 2 kg

WATER: 5 L/min

REMARKS

Poor separation. No heavy minerals band was formed.

RESULTS

No samples taken.

APPENDIX C

TABLE CONCENTRATION:
CONDITIONS AND RESULTS OF THE TESTS

TABLE TEST REPORT

DATE: 29/12/83

TEST: T-5

Ore ground to -0.25 mm

CONDITIONS

DECK: Sand

SLOPE: 7°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.25 + 0.074 mm (-60+200 mesh)

CHARGE: ~2 kg

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc-1	24.6	1.3	18.8	52.3
Conc-2	22.6	1.1	8.12	19.1
Midds	248.2	12.6	0.63	17.0
Tails	1675.3	85.0	0.064	11.6
Head	1970.7	100.0	0.468	100.0
Conc 1 + 2		2.4	13.9	71.4
Rougher Conc		15.0	2.75	88.4

TABLE TEST REPORT

DATE: 31/01/84

TEST: T-6

Ore ground to -0.3 mm

CONDITIONS

DECK: Sand

SLOPE: 7°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.3 + 0.074 mm (-48+200 mesh)

CHARGE: ~2 kg

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc-1	22.8	1.2	22.0	54.0
Conc-2	12.2	0.6	2.67	3.3
Midds	241.3	12.4	0.99	25.1
Tails	1672.0	85.8	0.10	17.6
Head	1948.3	100.0	0.49	100.0
Conc 1 + 2		1.8	15.6	57.3
Rougher Conc		14.2	2.84	82.4

TABLE TEST REPORT

DATE: 9/02/84

TEST: T-7

Ore ground to -0.425 mm

CONDITIONS

DECK: Sand

SLOPE: 7°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.425 + 0.074 mm (-35+200 mesh)

CHARGE: ~2000 g

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc-1	26.7	1.4	16.3	49.3
Conc-2	191.2	9.6	1.64	34.0
Midds	380.7	19.2	0.18	7.6
Tails	1383.6	69.8	0.06	9.1
Head (calc)	1982.2	100.0	0.46	100.0
Rougher Conc		30.2	1.53	90.9

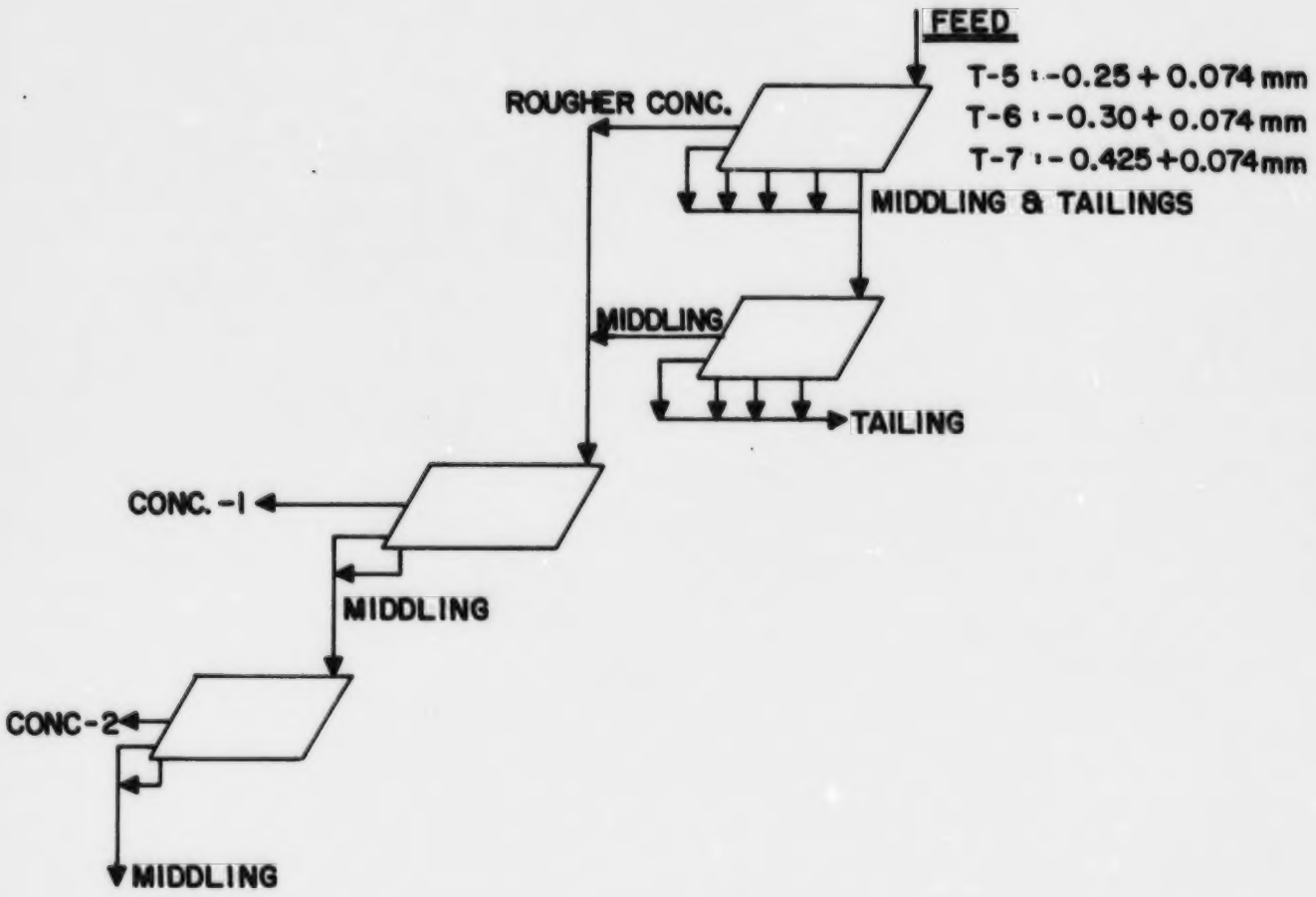

Fig T-5 Scheme of table tests T-5, T-6, T-7

TABLE TEST REPORT

DATE: 13/02/84

TEST: T-8

Ore ground to -0.25 mm

CONDITIONS

DECK: Sand

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.25 + 0.074 mm (-60+200 mesh)

CHARGE: ~2 kg

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Clean Conc	21.3	1.1	21.7	50.0
Midds	141.9	7.1	1.94	28.8
Tails	1824.9	91.8	0.11	21.2
Head (calc)	1988.1	100.0	0.477	100.0
Rougher Conc		8.2	4.59	78.8

TABLE TEST REPORT

DATE: 13/02/84

TEST: T-9

Ore ground to -0.3 mm

CONDITIONS

DECK: Sand

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.3 + 0.074 mm (-48+200 mesh)

CHARGE: ~2 kg

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Cleaner Conc	22.2	1.1	16.8	42.8
Midds	178.4	9.0	1.84	38.4
Tails	1780.7	89.9	0.09	18.8
Head (calc)	1981.3	100.0	0.431	100.0
Rougher Conc		10.1	3.47	81.2

TABLE TEST REPORT

DATE: 14/02/84

TEST: T-10

Ore ground to -0.425 mm

CONDITIONS

DECK: Sand

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.425 + 0.074 mm (-35+200 mesh)

CHARGE: ~2 kg

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Cleaner Conc	31.6	1.6	14.2	48.1
Midds	298.1	15.1	1.18	37.8
Tails	1645.7	83.3	0.08	14.1
Head (calc)	1975.4	100.0	0.472	100.0
Rougher Conc		16.7	2.43	85.9

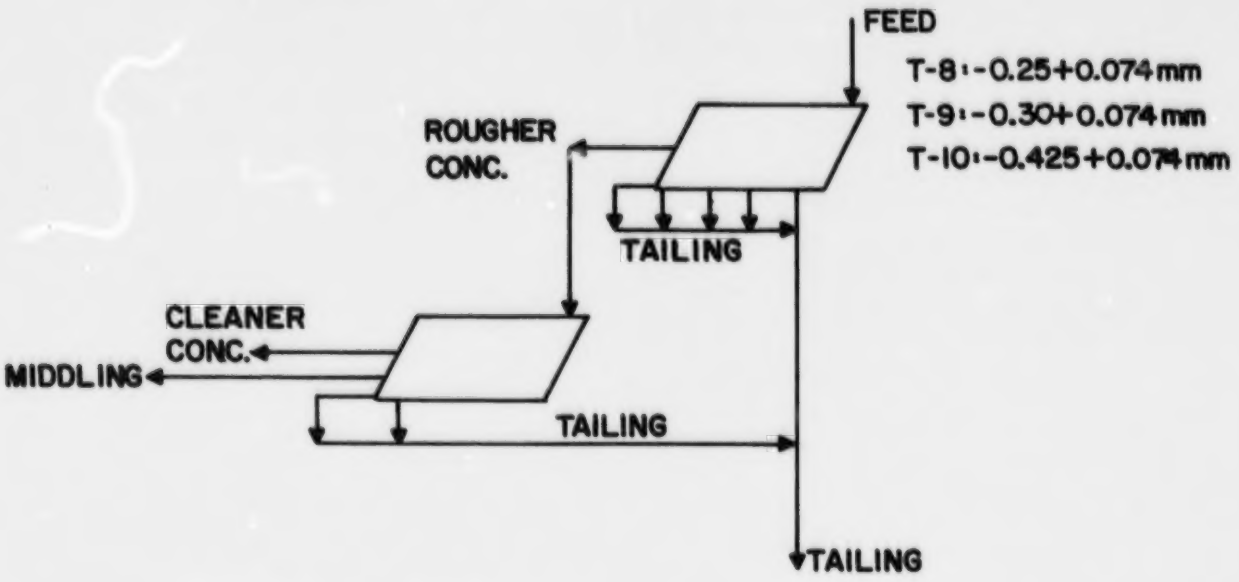

Fig. T-8 Scheme of table tests T-8, T-9, T-10.

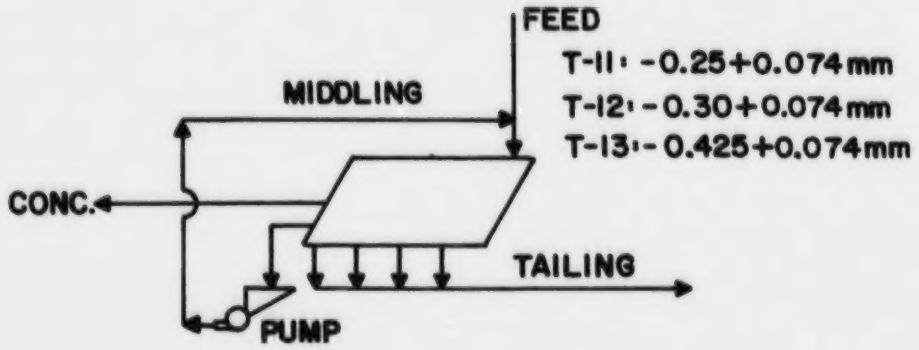

Fig. T-11 Scheme of table tests T-11, T-12, T-13

TABLE TEST REPORT

DATE: 14/02/84

TEST: T-11

Ore ground to -0.25 mm.

Recirculation of table middlings.

CONDITIONS

DECK: Sand

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.25 + 0.074 mm (-60+200 mesh)

CHARGE: ~2 kg

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	28.8	1.5	17.6	52.8
Tails	1939.5	98.5	0.24	47.2
Head (calc)	1968.3	100.0	0.50	100.0

TABLE TEST REPORT

DATE: 15/02/84

TEST: T-12

Ore ground to -0.3 mm

Recirculation of table middlings.

CONDITIONS

DECK: Sand

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.3 + 0.074 mm (-48+200 mesh)

CHARGE: ~2 kg

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	59.5	3.0	12.1	78.9
Tails	1926.3	97.0	0.I0	21.1
Head (calc)	1985.8	100.0	0.46	100.0

TABLE TEST REPORT

DATE: 15/02/84

TEST: T-13

Ore ground to -0.425 mm

Recirculation of table middlings.

CONDITIONS

DECK: Sand

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.425 + 0.074 mm (-35+200 mesh)

CHARGE: ~2 kg

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	68.3	3.5	9.35	79.8
Tails	1892.3	96.5	0.086	20.2
Head (calc)	1960.6	100.0	0.41	100.0

TABLE TEST REPORT

DATE: 29/02/84

TEST: T-14

CONDITIONS

DECK: Sand

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.25 + 0.074 mm (-60+200 mesh)

CHARGE: ~2 kg

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc-1	21.7	1.5	20.3	59.1
Conc-2	7.2	0.5	6.22	6.0
Conc-3	7.6	0.5	4.14	4.1
Midds	115.2	7.8	0.88	13.4
Tails	1318.7	89.7	0.10	17.4
Head (calc)	1470.4	100.0	0.516	100.0
Conc 1 + 2		2.0	16.8	65.1
Conc 1+2+3		2.5	14.3	69.2
Rougher Conc		10.3	4.14	82.6

TABLE TEST REPORT

DATE: 29/02/84

TEST: T-15

CONDITIONS

DECK: Sand

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.3 + 0.074 mm (-48+200 mesh)

CHARGE: ~1500 g

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc-1	20.8	1.5	20.4	63.6
Conc-2	6.5	0.5	5.64	5.9
Conc-3	6.4	0.4	2.57	2.1
Midds	116.5	8.1	0.36	6.1
Tails	1282.4	89.5	0.12	22.3
Head (calc)	1432.6	100.0	0.48	100.0
Conc 1 + 2	27.3	2.0	16.71	69.5
Conc 1+2+3	33.7	2.4	14.35	71.6
Rougher Conc		10.5	3.56	77.7

TABLE TEST REPORT

DATE: 5/03/84

TEST: T-16

CONDITIONS

DECK: Sand

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.425 + 0.074 mm (-35+200 mesh)

CHARGE: ~1500 g

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc-1	11.3	0.7	16.3	25.7
Conc-2	10.4	0.6	10.1	13.7
Conc-3	18.6	1.2	4.81	13.0
Midds	132.3	8.3	0.83	15.5
Tails	1420.0	89.2	0.16	32.1
Head (calc)	1592.6	100.0	0.444	100.0
Conc 1 + 2		1.3	13.43	39.4
Conc 1+2+3		2.5	9.29	52.4
Rougher Conc		10.8	2.79	67.9

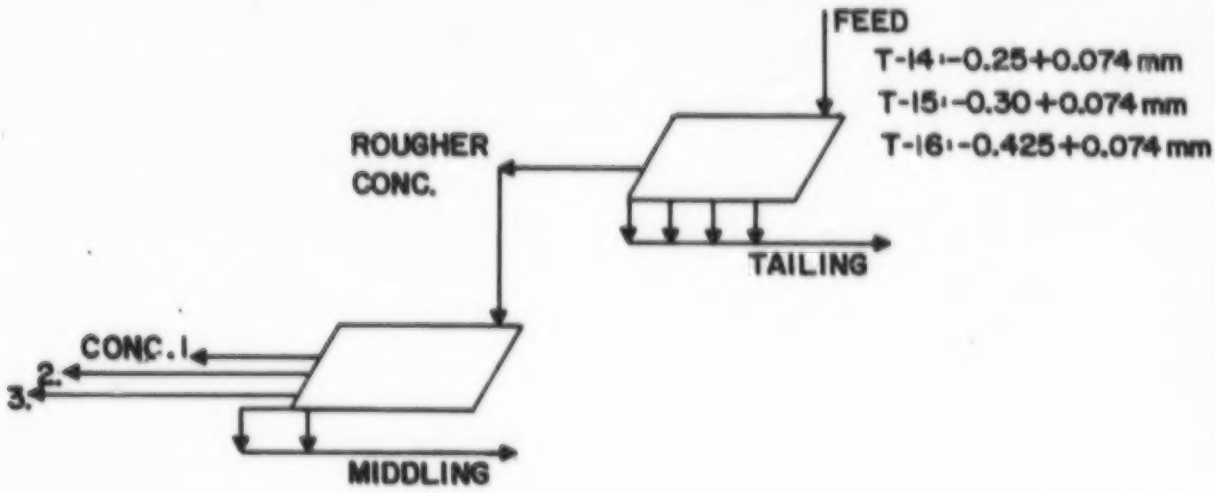

Fig. T-14 Scheme of table tests T-14, T-15, T-16

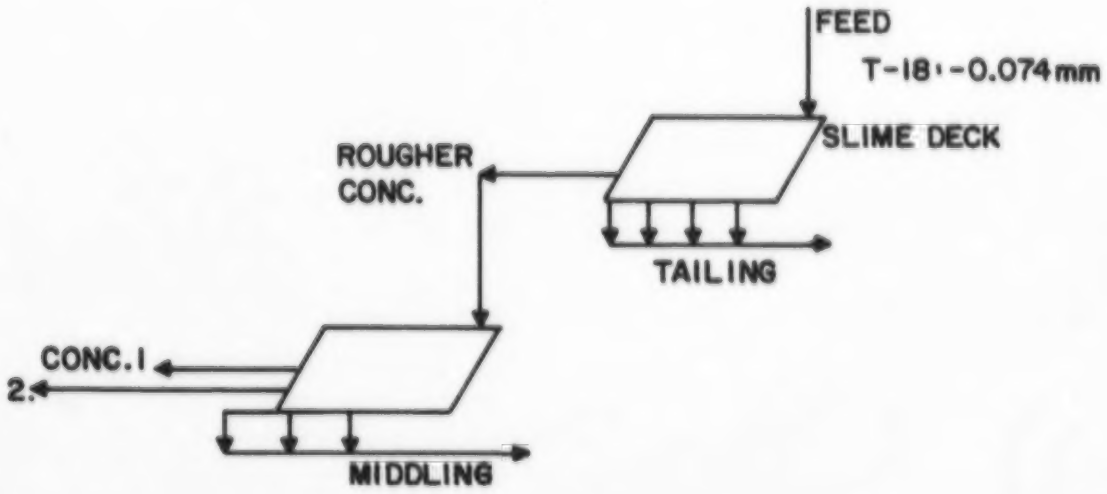

Fig. T-18 Scheme of table test T-18

TABLE TEST REPORT

DATE: 9/04/83

TEST: T-18

CONDITIONS

DECK: Slime

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.074 mm (-200 mesh) resulting from -0.3 mm grinding

CHARGE: ~1.5 kg

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc-1	13.5	0.8	11.2	19.9
Conc-2	39.0	2.4	1.40	7.5
Midds	124.5	7.6	0.30	5.1
Tails	1465.7	89.2	0.34	67.5
Head	1642.7	100.0	0.45	100.0
Rougher Conc		10.8	1.35	32.5

APPENDIX D

SPIRAL CONCENTRATION
CONDITIONS AND RESULTS OF THE TESTS

SPIRAL TEST REPORT

DATE: 25/01/84
TEST: SP-1

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1780

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	4	3	3	-	1	-	-	2	-	-	2	-	-	2
PRODUCT	C	C	C	C		C			M			M			M

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Conc	18.0	4373	26.238	57.5	2512.6	15.076	0.905	
Midds	6.6	1886	11.316	62.4	1177.2	7.063	0.424	
Tails	102.0	20,090	120.540	5.3	6392.3	38.354	2.301	
Head (calc)	126.6	26,349	158.094	38.3	10,082.1	60.493	3.630	
Excess WW								6.86
Feed				25.0				

WW = Wash Water

Test not conclusive (sanding in the sump)

RESULTS

Products	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	24.9	1.31	52.9
Midds	11.7	1.02	19.3
Tails	63.4	0.27	27.8
Head (calc)	100.0	0.62	100.0

SPIRAL TEST REPORT

DATE: 30/01/84
TEST: SP-2

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1350

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	-	4	-	3	-	2	-	-	2	-	-	2	-	-	1
PRODUCT		C		C		C		C			M			M	

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Conc	12.00	3118	18.708	56.0	1745.4	10.472	0.628	
Midds	3.96	1075	6.450	59.0	633.9	3.803	0.228	
Tails	93.00	15237	91.422	16.4	2493.0	14.958	0.897	
Head (calc)	108.96	19430	116.580	25.1	4872.3	29.233	1.753	
Feed		12958		37.6	4872.3			
WW in Products								38.832
Excess WW								3.492
Total WW								42.324

WW = Wash Water

Feed density Marcy balance: 37% solids

RESULTS

Products	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	35.8	0.94	78.6
Midds	13.0	0.24	7.2
Tails	51.2	0.12	14.2
Head (calc)	100.0	0.43	100.0
Head (assay)		0.45	

SPIRAL TEST REPORT

DATE: 6/02/84
TEST: SP-3

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1550

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	.	-	4	-	3	-	2	-	-	2	-	-	2	-	-	1
PRODUCT		C		C		C		C			M			M	

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Conc	12.0	2844.2	17.065	55.2	1569.5	9.417	0.565	
Midds	3.6	970.4	5.822	56.1	544.2	3.265	0.196	
Tails	114.0	20543.5	123.261	18.9	3884.4	23.306	1.398	
Head (calc)	129.6	24358.1	146.148	24.6	5998.1	35.988	2.159	
Feed	92.3	17851.5		33.6				
Excess WW								4.855
WW in Products								39.042
Total WW (calc)								43.897
Total WW (direct)								40.620

WW = Wash Water

Feed density, Marcy balance: 35.0% solids

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1569.5	26.1	1.36	72.4
Midds	544.2	9.1	0.42	7.8
Tails	3884.4	64.8	0.15	19.8
Head(calc)	5998.1	100.0	0.49	100.0
Head (assay)			0.46	

SPIRAL TEST REPORT

DATE: 7/02/84
TEST: SP-4

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1140

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	4	-	3	-	2	-	-	2	-	-	2	-	-	1
PRODUCT	C		C		C			C				M			M

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Conc	15.0	3289	19.734	57.8	1901.1	11.406	0.684	
Midds	3.6	683	4.098	55.6	379.9	2.279	0.137	
Tails	69.0	11691	70.146	15.5	1810.8	10,865	0.652	
Head (calc)	87.0	15663	93.978	26.1	4091.8	24.550	1.473	
Feed	66.7	11089		36.9	4091.8			
Excess WW								2.940
WW in products								27.444
Total WW (calc)								30.384
Total WW (direct)								35.040

WW = Wash Water

Feed density Marcy balance: 37% solids

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1901.1	46.5	0.86	85.1
Midds	379.9	9.3	0.18	3.6
Tails	1810.8	44.2	0.12	11.3
Head (calc)	4091.8	100.0	0.47	100.0
Head (assay)			0.52	

SPIRAL TEST REPORT

DATE: 7/05/84
TEST: SP-5

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

Used - normal WW (no scoops)
- low rpm
- low feed density

CONDITIONS

PUMP R.P.M.: 1140

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	4	-	3	-	2	-	-	2	-	-	2	-	-	1
PRODUCT	C		C		C			C				M			M

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Conc	12.0	2059.0	15.443	52.7	1085.0	8.138	0.488	
Midds	1.4	236.2	1.772	35.5	83.9	0.629	0.038	
Tails	75.0	9307.0	69.803	8.5	795.1	5.963	0.358	
Head (calc)	88.4	11602.2	87.018	16.9	1964.0	14.730	0.884	
Feed	74.4	8357.4		23.5	1964.0		1.2 (direct measurement)	
Excess WW								3.360
WW in products								24.338
Total WW (calc)								27.698
Total WW (direct)								30.375

WW = Wash Water

Feed density Marcy balance before sampling: 25% solids

RESULTS

Products	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	55.2		
Midds	4.3	No assay	
Tails	40.5		

SPIRAL TEST REPORT

DATE: 8/03/84
TEST: SP-6

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)
Used - increased WW (scoops)
- low rpm
- high slurry density

CONDITIONS

PUMP R.P.M.: 1140

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	4	-	3	-	2	-	-	2	-	-	2	-	-	1
PRODUCT		C		C		C			C			M			M

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt. g	Kg/min	% Solids	Wt. g	Kg/min	T/h	L/min
Conc	15.0	2816.3	21.122	58.7	1652.7	12.395	0.744	
Midds	4.05	800.1	6.001	55.2	441.7	3.312	0.199	
Tails	67.5	9193.5	68.951	10.4	959.1	7.193	0.432	
Head (calc)	86.55	12809.9	96.074	23.8	3053.5	22.900	1.375	
Feed		8625.7		35.4	3053.5		1.951	(direct measurement)
Excess WW								0.600
WW in products							"	31.380
Total WW (calc)								31.980
Total WW (direct)								36.000

WW = Wash Water

Feed density Marcy balance: 37.5% solids

RESULTS

Products	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	54.1		
Midds	14.5	No assay	
Tails	31.4		
Head (calc)	100.0		

SPIRAL TEST REPORT

DATE: 8/03/84
TEST: SP-7

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)
Used - increased WW (scoops)
- high rpm
- low slurry density

CONDITIONS

PUMP R.P.M.: 1540

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	4	-	3	-	2	-	-	2	-	-	2	-	-	1
PRODUCT	C		C		C			C			M				M

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt. g	Kg/min	% Solids	Wt. g	Kg/min	T/h	L/min
Conc	12.0	2456.9	18.427	56.3	1383.3	10.376	0.623	
Midds	3.0	595.1	4.463	49.7	295.8	2.218	0.133	
Tails	97.5	13393.0	100.448	9.1	1219.6	9.117	0.547	
Head (calc)	112.5	16445.0	123.338	17.6	2894.7	21.711	1.303	
Feed (direct)	96.0	12265.7		23.6	2894.7		1.551	(direct measurement)
Excess WW								1.200
WW in products								31.343
Total WW (calc)								32.543
Total WW (direct)								42.000

WW = Wash Water

Feed density Marcy balance: 25% solids

RESULTS

Products	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	47.8		
Midds	10.2	No assay	
Tails	42.0		
Head (calc)	100.0		

SPIRAL TEST REPORT

DATE: 13/03/84
TEST: SP-8

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)
Changed splitter setting

CONDITIONS

PUMP R.P.M.: 1550

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	3	-	2	-	2	-	-	2	-	-	1	-	-	c1
PRODUCT		C		C		C			C			M			M

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt. g	Kg/min	% Solids	Wt. g	Kg/min	T/h	L/min
Feed				29.9			1.9	

Slurry density by Marcy balance: 36 - 37% solids
Density inaccurately measured

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	1411.9	33.4		
Midds	769.4	18.2	No assay	
Tails	2052.0	48.4		
Head	4233.3	100.0		

SPIRAL TEST REPORT

DATE: 13/03/84
TEST: SP-9

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)
Further closing of ports

CONDITIONS

PUMP R.P.M.: 1550
SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	2	-	1	-	1	-	-	1	-	-	1	-	-	<1
PRODUCT		C		C		C			M			M			

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt. g	Kg/min	% Solids	Wt. g	Kg/min	T/h	L/min
Feed				26.7			1.6	

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc	808.7	22.3		
Midds	774.3	21.4	No assay	
Tails	2039.0	56.3		
Head	3622.0	100.0		

SPIRAL TEST REPORT

DATE: 16/03/84
TEST: SP-10

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1520

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	4	-	2	-	1	-	-	1	-	-	1	-	-	-
PRODUCT		C		C		C			C			M			

C = Cone; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt. g	Kg/min	% Solids	Wt. g	Kg/min	T/h	L/min
Feed				30.0			1.79	

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Port-2	71.1	1.8	2.75	6.8
Port-4	291.4	7.3	3.26	32.7
Port-6	137.8	3.5	2.18	10.9
Port-1	350.1	8.8	1.94	18.6
Midds	504.3	12.7	0.71	12.4
Tails	2624.6	65.9	0.21	19.0
Head (calc)	3979.3	100.0	0.728	100.0
Head (assay)			0.88	

SPIRAL TEST REPORT

DATE: 16/03/84
TEST: SP-11

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1520

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PRODUCT		C	C	C		C				M					

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt. g	Kg/min	% Solids	Wt. g	Kg/min	T/h	L/min
Feed				30.0			1.9	

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Port-2	97.8	2.3	1.90	7.0
Port-4	216.9	5.1	3.27	26.8
Port-6	90.0	2.1	2.47	8.3
Port-9	183.0	4.3	2.72	18.8
Midds	398.5	9.4	0.96	14.5
Tails	3260.7	76.8	0.20	24.6
Head (calc)	4246.9	100.0	0.62	100.0
Head (assay)			0.66	

SPIRAL TEST REPORT

DATE: 19/01/84
TEST: SP-12

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1150
SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	-	6	-	2	-	1	-	-	1	-	-	1	-	-
PRODUCT			C		C		C			C			M		

C = Cone; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt. g	Kg/min	% Solids	Wt. g	Kg/min	T/h	L/min
Feed				30.0			1.69	

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Port-2	178.2	4.8	2.14	16.9
Port-4	413.8	11.0	1.80	31.8
Port-6	258.3	6.9	1.52	16.8
Port-9	500.4	13.3	0.77	16.4
Midds	611.9	16.3	0.33	8.6
Tails	1787.5	47.7	0.13	9.9
Head (calc)	3750.1	100.0	0.62	100.0
Head (assay)			0.67	

SPIRAL TEST REPORT

DATE: 19/03/84
TEST: SP-13

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1150

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	3	-	1	<1	-	<1	-	-	-	<1	-	-	-	-
PRODUCT		C		C	C		C				M				

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Feed				30.0			1.37	

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Port-2	72.2	2.4	2.66	9.1
Port-4	298.6	9.8	2.25	31.3
Port-6	187.9	6.2	1.79	15.7
Port-9	419.7	13.8	1.14	22.3
Midds	355.1	11.6	0.44	7.2
Tails	1714.8	56.2	0.18	14.4
Head (calc)	3048.3	100.0	0.71	100.0
Head (assay)			0.72	

SPIRAL TEST REPORT

DATE: 3/04/84
TEST: SP-14

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1550

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	3	-	2	-	1	-	-	1	-	-	1	-	-	-
PRODUCT		C		C		C			C			M			

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Feed				30.0			1.8	

Slurry density by Marcy balance: 38% solids

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Port-2	63.8	1.6	2.09	5.5
Port-4	334.7	8.2	2.51	33.7
Port-6	217.5	5.4	1.93	17.0
Port-9	362.2	8.9	1.03	15.0
Midds	562.9	13.9	0.51	11.6
Tails	2516.4	62.0	0.17	17.2
Head (calc)	4057.5	100.0	0.61	100.0
Head (assay)			0.54	

SPIRAL TEST REPORT

DATE: 3/04/84
TEST: SP-15

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1550

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	3	-	2	-	1	-	-	1	-	-	-	1	-	-	-
PRODUCT		C		C		C			C			M			

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Feed				27.1			1.5	

Slurry density by Marcy balance: 30% solids

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Port-2	47.1	1.4		
Port-4	278.4	8.2		
Port-6	186.6	5.5		
Port-9	302.8	8.9	No assay	
Midds	343.4	10.1		
Tails	2241.7	65.9		
Head (calc)	3400.0	100.0		

SPIRAL TEST REPORT

DATE: 9/04/84
TEST: SP-16

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1550

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	3	-	2	-	2	-	-	1	-	-	1	-	-	-
PRODUCT		C		C		C			C			M			

C = Conc; M = Midduling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Feed				38.9			2.4	

Slurry density by Marcy balance: 38% solids

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Port-2	89.1	1.7	1.46	5.4
Port-4	341.3	6.5	1.91	26.9
Port-6	191.4	3.6	1.61	12.6
Port-9	288.3	5.5	1.17	13.9
Midds	465.8	8.9	0.65	12.5
Tails	3881.2	73.8	0.18	28.7
Head (calc)	5257.1	100.0	0.46	100.0
Head (assay)			0.51	

SPIRAL TEST REPORT

DATE: 11/04/84
TEST: SP-17

FEED

SIZE: -1.7 mm (-10 mesh) no classification

CONDITIONS

PUMP R.P.M.: 1550

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	3	-	2	-	1	-	-	1	-	-	1	-	-	-
PRODUCT		C		C		C			C			M			

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Feed				40.0			2.3	

Slurry density by Marcy balance: 38%; 40% solids

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Port-2	101.1	2.0	1.38	6.0
Port-4	246.4	4.8	1.85	19.4
Port-6	89.5	1.8	2.79	11.0
Port-9	161.7	3.2	1.61	11.3
Midds	219.9	4.3	1.25	11.9
Tails	4292.8	83.9	0.22	40.4
Head (calc)	5111.4	100.0	0.46	100.0
Head (assay)			0.44	

SPIRAL TEST REPORT

DATE: 11/04/84
TEST: SP-18

FEED

SIZE: -1.7 mm (-10 mesh) no classification

CONDITIONS

PUMP R.P.M.: 1550

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	3	-	2	-	1	-	-	1	-	-	1	-	-	-
PRODUCT		C		C		C			C			M			

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Feed				34.9			1.9	

Slurry density by Marcy balance: 31.0% solids

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Port-2	75.5	1.8		
Port-4	215.7	5.1		
Port-6	91.0	2.1	No assay	
Port-9	128.7	3.0		
Midds	283.2	6.7		
Tails	3450.8	81.3		
Head	4244.9	100.0		

SPIRAL TEST REPORT

DATE: 12/04/84
TEST: SP-19

FEED

SIZE: -1.7 mm (-10 mesh) no classification

CONDITIONS

PUMP R.P.M.: 1550

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	3	-	2	-	1	-	-	1	-	-	1	-	-	-
PRODUCT		C		C		C			C			M			

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Feed				30.0			2.1	

Slurry density by Marcy balance: 29%; 32%; 29% solids

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Port-2	60.4	1.3	1.35	4.2
Port-4	208.5	4.4	1.87	19.4
Port-6	80.5	1.7	3.39	13.6
Port-9	118.8	2.5	2.01	11.9
Midds	276.3	5.8	1.11	15.2
Tails	4020.5	84.3	0.18	35.7
Head (calc)	4765.0	100.0	0.42	100.0
Head (assay)			0.39	

SPIRAL TEST REPORT

DATE: 12/04/84
TEST: SP-20

FEED

SIZE: -1.7 mm (-10 mesh) no classification

CONDITIONS

PUMP R.P.M.: 1550

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTING	-	5	-	3	-	2	-	-	2	-	-	2	-	-	-
PRODUCT		C		C		C			C			M			

C = Conc; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt, g	Kg/min	% Solids	Wt, g	Kg/min	T/h	L/min
Feed				27.7			1.9	

Slurry density by Marcy balance: 29% solids

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Port-2	132.1	3.2	1.62	11.1
Port-4	301.9	7.2	1.96	30.2
Port-6	232.9	5.6	1.50	18.0
Port-9	302.1	7.2	0.75	11.5
Midds	444.9	10.7	0.35	8.0
Tails	2758.7	66.1	0.15	21.2
Head (calc)	4172.6	100.0	0.47	100.0
Head (assay)			0.47	

APPENDIX E

FLOWSHEET-1, TABLE CONCENTRATION

FLOWSHEET-2, SPIRAL AND TABLE CONCENTRATION

CONDITIONS AND RESULTS OF THE TESTS

TABLE TEST REPORT

DATE: 16/04/84

TEST: T-19 (Flowsheet #1)
Ore ground to -0.3 mm

CONDITIONS

DECK: Sand

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.3 + 0.074 mm (-48+200 mesh)

CHARGE: ~1500 g

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc-1	1.5	20.4	63.6
Conc-2	0.5	5.64	5.9
Midds	8.5	0.47	8.2
Tails	89.5	0.12	22.3
Head (calc)	100.0	0.48	100.0

TABLE TEST REPORT

DATE: 16/04/84

TEST: T-19 (cont'd) Flowsheet #1

The feed was a composite of the -0.074 mm fraction resulting from grinding the ore to -0.3 mm and the Sand Table Middling reground to -0.074 mm.

CONDITIONS

DECK: Slime

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.074 mm (-200 mesh)

CHARGE: ~2 kg

WATER: 5 L/min

REMARKS

Grinding Middlings

Mill: 200 mm diam, porcelain. Grinding balls: 8632 g steel. Slurry density: 60% solids. Charge: 250 g. Time: 3 min.

RESULTS

Products	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc-3	0.5	14.7	13.9
Conc-4	0.2	5.69	2.2
Scav. Conc-1	0.7	2.42	3.2
Scav. Conc-2	4.0	1.00	7.5
Scav. Tails	94.6	0.41 (calc)	73.2
Head (calc)	100.0	0.53	100.0

SPIRAL TEST REPORT

DATE: 3/04/84

TEST: SP-14 (Flowsheet #2)

FEED

SIZE: -1.7 + 0.074 mm (-10+200 mesh)

CONDITIONS

PUMP R.P.M.: 1550

SPLITTER SETTINGS:

PORT #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SETTIN.	-	3	-	2	-	1	-	-	1	-	-	1	-	-	-
PRODUCT		C		C		C			C			M			

C = Cone; M = Middling

MATERIAL BALANCE

	Slurry				Solids			Water
Products	L/min	Wt. g	Kg/min	% Solids	Wt. g	Kg/min	T/h	L/min
Feed				30.0			1.8	

RESULTS

Products	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Cone	24.1	1.81	71.2
Midds	13.9	0.51	11.6
Tails	62.0	0.17	17.2
Head (calc)	100.0	0.61	100.0

TABLE TEST REPORT

DATE: 8/05/84

TEST: T-20 (Flowsheet #2)

Tabling ground spiral concentrate.

CONDITIONS

DECK: Sand

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.3 + 0.074 mm (-48+200 mesh) Spiral Conc

CHARGE: ~4 kg

WATER: 5 L/min

REMARKS

Grinding Spirals Conc to -0.3 mm

Charge: 2100 g. Mill: 250 mm diam, ceramic. Grinding balls: 11.350 kg steel. Slurry density: 60% solids. Time: 8 + 10 min.

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc-1	121.7	3.0	30.0	58.4
Conc-2	27.7	0.7	21.3	9.7
Conc-3	64.6	1.6	9.02	9.4
Conc-4	5.1	0.1	17.5	1.1
Midds-1	187.2	4.7	2.29	7.0
Midds-2	1130.9	28.5	0.48	8.9
Tails-1	2509.6	61.4	0.14	5.5
Head (calc)	4082.4	100.0	1.54	100.0

TABLE TEST REPORT

DATE: 14/05/84

TEST: T-21 (Flowsheet #2)

The feed was formed by compositing the -0.074 mm fractions resulting from the initial screening of the ore and from screening the ground spiral concentrate with the reground Sand Table Middling-1.

CONDITIONS

DECK: Slime

SLOPE: 6°

STROKE: 12 mm

S.P.M: 104

FEED

SIZE: -0.074 mm (-200 mesh)

CHARGE: ~2 kg

WATER: 5 L/min

REMARKS

RESULTS

Products	Wt g	Wt %	Assay % Nb_2O_5	% Dist. Nb_2O_5
Conc-5	47.7	2.4	12.6	25.9
Midds-3	85.8	4.3	1.72	6.3
Tails-2	1847.2	93.3	0.85	67.8
Head (calc)	1980.7	100.0	1.17	100.0

APPENDIX F

CPDU SPIRAL TESTS
WEIGHT AND ASSAY OF PRODUCTS

RESULTS OF CPDU SPIRAL TESTS

Test No.	Product	Sampling time, sec.	Weight g	Slurry % solids	Assay % Nb_2O_5
Run #1	Fresh feed	Not measured	609.2	27.5	0.48
	Spiral feed	Not measured	816.1	29.3	0.52
	Middling	Not measured	168.5	19.8	0.91
	Concentrate	7	697.3	43.9	2.09
	Tailing	7	4314.6	16.7	0.22
Run #2	Fresh feed	4	1801.1	28.8	0.42
	Spiral feed	Not measured	1351.0	42.5	0.77
	Middling	15	325.3	24.4	0.48
	Concentrate	10	1366.2	51.2	1.36
	Tailing	10	3547.3	18.7	0.16
Run #3	Fresh feed @ 7 sec	5	2364.6	33.9	0.50
	Fresh feed @ 12 "	5	1751.2	26.8	0.46
	Fresh feed @ 17 "	5	2188.7	33.0	0.54
	Spiral feed @ 7 "	4	2164.4	30.3	0.43
	Spiral feed @ 12 "	4	2656.6	37.4	0.56
	Spiral feed @ 17 "	5	2387.5	26.6	0.53
	Middling @ 7 sec	5	141.1	26.2	0.73
	Middling @ 12 "	5	123.5	21.8	0.98
	Middling @ 17 "	5	112.5	22.0	0.77
	Concentrate	30	3627.7	49.9	1.46
	Tailing	30	11014.1	19.5	0.17